University of Maine at Presque Isle: Chemical Hygiene Plan

Table of Contents

University of Maine at Presque Isle: Chemical Hygiene Plan

I. Purpose and Scope

The University of Maine at Presque Isle is committed to providing a safe and healthy environment for all members of the Laboratory community and to reducing the incidence of disease and injury to the lowest achievable level.

This Chemical Hygiene Plan (CHP) is specific for the University of Maine at Presque Isle and is in compliance with the Department of Labor Occupational Safety and Health Administrations (OSHA) published final rule for occupational exposure to hazardous chemicals in laboratories [29 CFR 1910.1450] OSHA Standards 29 CFR

The objective of this CHP is to describe the work practices, procedures, personal protective equipment and other equipment that will protect University of Maine employees from harm arising from the storage and use of hazardous chemicals in the laboratory. However, the information in this CHP must be supplemented by laboratory specific information, policies and procedures.

This Chemical Hygiene Plan will be reviewed annually.

II. Responsibilities

University of Maine System Office of Safety and Environmental Management
Develop and update as needed a general guidance document outlining the format and subject matter that should be covered as required by pertinent regulations in all laboratory safety plans. Offers technical guidance and assistance to campus Chemical Hygiene Officers. Maintain resources that may be used by individual campuses through the Chemical Hygiene Officer to assist in the implementation of training requirements outlined in this plan. Random inspections of laboratories to ensure laboratory safety plans are in place, effective, and being followed. Conduct safety audits of laboratories on request and make recommendations to improve safety within the laboratory.

Regulatory Compliance Officer and Safety and Security Officer-
Oversees emergency preparedness and response, as well as regulatory compliance issues including the documentation of training. Reviews the Chemical Hygiene Plan with the Chemical Hygiene Officer annually.

University Chemical Hygiene Officer –
Ensure each laboratory within the science department has an effective laboratory safety plan that is followed by persons teaching or working in the laboratory on a routine basis. Reviews laboratory safety plans before being implemented and on an annual basis after implementation to ensure they are complete and effective. Ensure proper training is provided as described in this plan. Ensures all

laboratory instructors are effectively training students prior to starting any lab work. Maintain documentation as to who has been trained in laboratory safety as required by this plan. Ensure all new personnel, as part of their orientation, have reviewed the laboratory safety plan, understand its requirements, and follow those requirements. Ensure all laboratory personnel have been trained in the proper use of safety equipment (such as laboratory ventilation hoods, fire extinguishers, emergency showers and eyewash stations). See Lab Plan Training Sheet at end of this section. Ensure new lab instructors have been properly equipped with personal protective equipment (if necessary) and trained in its proper use. Advise instructors as to emergency procedures to be used in the event of a fire, spill, toxic release, personal injury, or other accident. In collaboration with Facilities Management, ensure necessary safety and personal protective equipment (such as spill kits, laboratory ventilation hoods, emergency showers and eyewash stations, fire extinguishers, safety shields, safety glasses, proper gloves, respirators, and other necessary apparel) is provided prior to any operation that may require such equipment. Maintain a chemical inventory for the science labs, identify potential hazards posed to instructors, students and lab workers, and provide additional training as needed.

Department of Facilities (Physical Plant)-

Provide routine maintenance of laboratory safety equipment (such as laboratory ventilation hoods, emergency eyewash and shower stations, and general laboratory ventilation) as needed or on request by the department having such equipment. Provide support in emergency preparedness and in emergency situations. In support of the Chemical Hygiene Officer, provide training to laboratory personnel in the proper use of emergency equipment such as fire extinguishers. Provide training to facilities staff on chemical hygiene and safety, maintain MSDS sheets and other safety information for facilities management activities of areas of the university that are not science laboratories and manage universal waste generated on campus. Inform personnel about special or unusual hazards related to non-routine work.

Human Resources

Human Resources (HR) maintains records of medical testing and surveillance as required under the Lab Standard, coordinates baseline medical surveillance and manages workers' compensation claims.

Instructors and students

Instructors will ensure that students review the laboratory safety plan prior to conducting any laboratory work, are trained in laboratory safety practices and equipment, and sign lab safety agreements. Ensure that laboratory work will be conducted with good safety practices and be prepared in advance for possible accidents by knowing what emergency aids are available and how they are to be used. Advise any new employees or students in the laboratory of the laboratory safety plan, necessary safety equipment, and emergency procedures. Communicate with Chemical Hygiene Officer about chemicals received and placed in inventory and about any hazardous waste that is generated in the laboratory. Correctly label and store hazardous waste produced. Practice good personal safety habits.

Officers & Departments:

Regulatory Compliance Officer and Safety and Security Officer: FRED THOMAS

____

181 Main St.
University of Maine at Presque Isle
Presque Isle, ME 04769
207-768-9580

Chemical Hygiene Officer: JUDITH ROE

____

181 Main St.
University of Maine at Presque Isle
Presque Isle, ME 04769
207-768-9450 (-9446)

Facilities Management: JOSEPH MOIR

____

181 Main St.
University of Maine at Presque Isle
Presque Isle, ME 04769
207-768-9576

Human Resources manager: DORIANNE PRATT

____

181 Main St.
University of Maine at Presque Isle
Presque Isle, ME 04769
207-768-9551

III. LAB SAFETY PLAN

The purpose of this plan is to provide a safe laboratory work environment for the employees and students of the University of Maine at Presque Isle. Each plan is intended to: *Protect laboratory employees and students from health hazards associated with the use of hazardous chemicals in our laboratories; and *Assure that our laboratory employees and students are not exposed to substances in excess of the permissible exposure limits (PEL's) as defined by the Occupational Safety and Health Administration (OSHA) and codified in 29 CFR 1910.1000, Table Z-A-A; 1 (https://www.osha.gov/dsg/annotated-pels/) and *Assist with laboratories regulatory compliance with OSHA Laboratory Standard as codified in 29 CFR 1910.1450. These plans will be available to all employees and students for review, and a copy will be located in each appropriate laboratory. The plans will be reviewed annually and updated as necessary by the chemical hygiene officer. Alternative recommended exposure levels are recommended by the American Conference of Governmental

Industrial Hygienists (ACGIH) and the National Institute of Occupational Safety and Health (NIOSH). If exposure levels differ between OSHA, ACGIH, or NIOSH, the lowest recommended level will be used.
The Laboratory Safety Plan for the classroom and research laboratories, and the student agreement forms and chemical hygiene information forms are presented below.

EMERGENCY PHONE NUMBERS
*For immediate emergency service- 8-911
*Campus Safety and Security- 207-768-9580
*Campus Main Number- 207-768-9500
*After Hours Campus Security- 207-768-9600
*Facilities Management –207-768-9576
*Chemical Hygiene Officer –207-786-9450 (-9446)
*Northern New England Poison Center: 1-800-222-1222
*National Response Center: 1-800-424-8802

LAB SAFETY PLAN

A.PURPOSE

This laboratory safety plan sets forth policies, procedures, equipment, personal protective equipment, and work practices that are capable of protecting University personnel and students from the health and safety hazards inherent in laboratories. The primary goal of this plan is to assist in making the laboratory a safer place to work. The secondary goal of this plan is to meet various state and federal regulations such as Title 29 of the Code of Federal Regulations Part 1910.1450, "Occupational Exposures to Hazardous Chemicals in Laboratories." A copy of this standard may be found in Appendix A and at: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10106&p_table=STANDARDS.

Safe Work Practices

To minimize exposure to hazardous substances in the laboratory, the following practices must be followed including hazard awareness, the use of engineering controls, personal protective equipment (PPE), and good laboratory practices. These will reduce employee exposure to hazardous chemicals. In addition, training will be provided on general laboratory safety for employees and students.

Hazard Awareness Policy: Employees must know the following information about each chemical or chemical group prior to its use [all information is available in the Safety Data Sheets (SDS) accompanying any hazardous chemical]:

a. The name of the chemical and its hazardous component(s);
b. The health and physical risk(s) associated with the chemical;
c. Signs of release and symptoms of exposure;
d. How and when to use engineering controls and personal protective equipment;
e. Labeling and storage requirements;
f. Disposal procedures;
g. Emergency procedures for spills and exposures;

General Safety Practices: Lab workers should follow the general practices listed below (more information can be found in Appendix A: Standard Operating Procedures):

- No food or drink in the laboratory at any time.
- Use protective clothing (gloves, lab coats, face masks, eye protection) whenever working with any hazardous chemical.
- Be familiar with the chemicals you use. Refer to Safety Data Sheets/Material Safety Datasheets records in your lab
- Use a fume hood for all hazardous gases, vapors, dusts or aerosols.
- Use safety shield to protect from dangerous reaction conditions.
- Know when to institute special procedures when using "Particularly Hazardous Substances", such as highly toxic or carcinogenic substances.
- Know the locations and uses of the nearest eyewash, shower, fire extinguisher, gas shutoffs, building escape route, first aid kit and spill kit.
- Store Chemicals in their proper places. Chemicals may be kept in cabinets on shelves in laboratories, and chemicals should be returned to their place when not in use. Incompatible chemicals should not be stored together. Chemicals should be inventoried often and chemicals used infrequently should be moved to the vented storage cabinets in the Chemical Storage Room Folsom 103B. Chemicals may be stored underneath hoods, but these

areas are not vented and this should be taken into consideration in choice of storage location.

- Prepare and Store Hazardous Waste as outlined by the Hazardous Waste Plan. Chemical waste should be placed in secure containers, marked as “hazardous waste” preferably with a special label and labeled with the contents written clearly including the date, the amount and the chemical composition of the waste. These waste containers should be placed in a satellite waste station (Folsom 202, under the exhaust hood at the South end of the room) and the Chemical Hygiene officer should be informed of the item(s). If appropriate, it may also be placed in the main Hazardous Waste vented cabinet in Folsom 103B. A secondary container should be used in these storage areas to prevent further spills. If a “hazardous waste” container is being filled over time in a laboratory, a log should be readily available and personnel should mark any entries on the log. The container should never be left open! When full, the container should be secured and placed in the satellite pick-up area or the main cabinet, or ask the Chemical Hygiene officer to pick-up.
- Report any injury or spill to a science faculty member or your immediate supervisor, Facilities Management and the chemical hygiene officer.

A.WHEN TO USE A LABORATORY VENTILATION HOOD

A laboratory ventilation hood or a laboratory "fume" hood when used properly is the most effective way to minimize exposure to hazardous substances. Depending on the specific unit, a laboratory ventilation hood can offer up to three types of protection:

1. Local ventilation of gases, vapors, fumes, or particles
2. Shielding from splash, fire, and minor explosions
3. Containment of spills

A ventilation hood that has been tested and certified (see Section 6) for use should be used whenever manipulations of chemical substances are occurring regardless of toxicity. When handling toxic substances and highly toxic substances, a fume hood shall always be used. Additionally, when handling toxic and highly toxic substances, a laboratory ventilation hood's performance should be verified before manipulation of those substances by turning on the hood and checking that the automated alarm system indicator lights indicate a working system before opening any chemicals and that any other information present on the alarm system indicates the system is working properly. Verify that the lights are working as well.

All substances that become volatile at room temperature or are flammable shall be manipulated in a certified hood. Any heating of substances should occur inside a certified hood especially if heating places substance above the flash point temperature or causes volatilization.

B.WHEN TO USE SAFETY SHIELDS OR OTHER CONTAINMENT DEVICES

Whenever there is a distinct possibility that an explosion or splashing of chemical substances could occur, safety shields or containment devices should be used. Most laboratory ventilation hoods are equipped with sashes that may provide splash and minor explosion protection. Sashes should be lowered as much as reasonably possible especially during the heating or reacting of substances.

If you are conducting experiments under reduced or increased pressures, safety shielding should be used at all times to protect from implosion or explosion hazards. Sometimes pressure buildup is an unwanted byproduct of a reaction or accidental reaction, always be cautious when conducting reactions and use safety shields whenever possible.

C.WHEN TO USE PERSONAL PROTECTIVE EQUIPMENT

Eye Protection

Generally, no one should enter any laboratory without appropriate or suitable eye protection while any manipulation or reaction processes are occurring. Eye protection should be worn at all times in the laboratory. Selection of this protection should be made based on work being conducted in the area. If there is a possibility of something being splashed, make sure you are wearing goggles. Safety glasses should be used only to protect from impact of projectiles (such as glass). (See Appendix A-2)

Gloves

Gloves that are impermeable to the substances being handled should be worn whenever there is a possibility of exposure of a hazardous substance to the skin. The best practice is to make sure no substance comes in contact with the skin since this is a primary pathway for certain chemicals to be absorbed into the body.

[Respirators

Respiratory protection is to be used only after it is found that exposure to a particular substance cannot be controlled by using engineering controls. OSHA states in 29 CFR 1910.134 "[i]n the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination." Only after all other efforts to prevent exposure have been exhausted, may respiratory protection be used.

If respiratory protection is going to be used, no one may wear a respirator unless a respiratory protection program has been established as described in 29 CFR 1910.134 and the persons planning on utilizing respiratory protection are tested and trained as required. If a respiratory protection program is in effect, it must be included with this laboratory safety plan.] (not in place)

D. WHEN TO INSTITUTE SPECIAL WORK PRACTICES: Particularly Hazardous Substances

Whenever working with a substance that has been listed or suspected as a carcinogen, teratogen, or is acutely or chronically toxic, Procedures A and B in Appendix A-5 must be used along with other recommendations found in that section. Laboratory personnel should establish a Standard Operating Procedure with the help of the Chemical Hygiene Officer, the University of Maine System Office of Safety and Environmental Management and/or Facilities Management.

LABORATORY SAFETY EQUIPMENT

{29 CFR 1910.1450 (e)(3)(ii)}

LABORATORY VENTILATION HOODS

Laboratory ventilation or "fume" hoods are intended to protect laboratory workers and students conducting experiments from exposure to hazardous vapors, dust, and fumes. In addition, laboratory ventilation hoods may protect building occupants from hazardous gases evolving from the normal experiments, runaway reactions, or accidental spills. As such, the protection any hood gives is directly proportional to its functioning properly. The only way to judge a laboratory hood as effective is by testing the unit in a standardized way to ensure certain minimum requirements or standards is met.

The University of Maine System Laboratory Hood Testing Program establishes standards to ensure all University laboratory hoods are performing adequately. This program is limited to laboratory ventilation or "fume" hoods only and is not intended to apply to related safety devices such as biological safety cabinets, glove boxes, or canopy hoods.

A: Inspection and Certification

Inspection and testing of all laboratory ventilation hoods that are used in the University of Maine System shall occur when hoods are installed, modified, and at least once a year thereafter. In addition, testing should occur when requested by the user or campus Department of Facilities Management or Physical Plant.

The following standards are established in the testing and certification program:

1. The hood's interior, sash, and duct work show no obvious deterioration or failure.
2. Hood must maintain an average linear face velocity of 100-120 fpm at a sash height of at least 15 inches.
3. Hoods that do not meet the above standard may receive conditional certification for use if a 100-120 fpm average face velocity is met at a sash height of at least 10 inches. The hood may be used only at the minimum sash height where the average face velocity is 100 fpm.
4. Hoods which do not maintain an average face velocity of 100-120 fpm or have a maximum safe operating height of less than 10 inches will not be certified. These will be labeled "Do Not Use" and referred to facilities management for maintenance, repair, and/or modification.
5. Hoods should be used for the function(s) they were designed for. Special certification is required for laboratory hoods that are used to high pressure reactions, work involving perchloric acid, and the use of radioactive compounds. A detailed copy of this testing program may be found in Appendix E. Testing of laboratory ventilation of fume hoods on the campus will be conducted at least annually or upon request.

B: Preventive Maintenance

As with any piece of equipment, preventive maintenance helps to address breakdowns before they occur by replacing worn parts, identifying deterioration, and properly lubricating moving parts to prevent premature wearing. Preventive maintenance will be performed twice a year by your campus

Department of Facilities or Physical Plant. A detailed outline of the preventive maintenance process may be found in Appendix F.

C: Recommendations for New Laboratory Ventilation Hoods

The proper selection and installation of a laboratory ventilation hood is integral in providing adequate safety to its users. The University of Maine System recommends that new hoods conform with current industry standards. A detailed outline of recommendations for new laboratory ventilation hoods may be found in Appendix G.

D: Education and Training

All laboratory workers and students who will use or have available the use of laboratory hoods should be trained in their purpose, function, and proper operation including identification of hoods controls and how to use them. This education should be provided by the department responsible for a particular laboratory to bring better understanding towards the purposes and limitations of available laboratory hoods. Information regarding the description or use of laboratory ventilation hoods may be found in Appendix D.

EYEWASH STATIONS/EMERGENCY SHOWERS

All eyewash stations and emergency shower stations will be tested at least annually by your campus Department of Facilities Management or Physical plant. Laboratory supervisors are strongly encouraged to test this equipment at least once a month and preferably once a week. Any problems or mechanical failures should be reported to your campus Department of Facilities Management or Physical Plant immediately. All laboratory workers must be familiar with the use and location of these stations.

EMERGENCY SPILL KITS

Depending on the hazardous substances you are working with, emergency spill kits or clean up supplies may be necessary to properly neutralize or absorb spilled substances. If you are working with a hazardous substance make sure you have the proper equipment immediately available to clean up any spills. If you have commercially designed spill kits, they should be inspected at least once a month to ensure they are complete and that none of the components have passed their expiration date. All laboratory workers must be familiar with the equipment available and its limitations for cleaning up spills.

FIRE EXTINGUISHERS

All portable fire extinguishers located within the laboratory must be appropriate for the materials being handled and work being conducted in the laboratory. In addition, all extinguishers must be University Environmental Health and Safety 16 Laboratory Safety Plan tested, inspected and maintained as described in the University of Maine System's "Procedure For the Testing, Inspection and Maintenance of Life Safety Equipment and Systems (August 16, 1988 revision)." Contact the University Environmental Health and Safety Office for a copy of the proper procedure. All laboratory workers should be familiar with and trained in the use of portable fire extinguishers located in the laboratory.

REQUIRED APPROVALS

Laboratory operations that are conducted after normal business hours (the period of time when buildings are normally secured or locked), on weekends or holidays, or when there is no one else in the laboratory or laboratory building, may require prior approval. The science department gives initial approval for laboratory research upon hiring science faculty. The Chemical Hygiene officer must be advised of activity using particularly hazardous substances along with campus security staff. Any activities using highly toxic materials should be discussed with the Chemical Hygiene Officer and department colleagues who are knowledgeable about the materials, and a safety plan agreed upon before conducting the operation.

MEDICAL CONSULTATION AND EXAMINATION

{29 CFR 1910.1450 (e)(3)(vi)}

{The following was extracted and adapted from 29 CFR 1910.1450 (g)}

The University of Maine at Presque Isle will provide for all employees who work with hazardous chemicals the opportunity to receive medical attention, including any follow-up examinations which the examining physician determines as being necessary, under the following circumstances:

1. Whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory, the employee will be provided an opportunity to receive an appropriate medical examination.

2. Where exposure monitoring reveals an exposure level routinely above an OSHA established action level (or an OSHA established permissible exposure level if no action level has been established) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance will be established for the affected employees as prescribed by the particular standard.

3. Whenever an event takes place in the work area such as a spill, leak, explosion, or other occurrence resulting in the likelihood of a hazardous exposure, the affected employee will be provided an opportunity for a medical consultation for the purpose of determining the need for a medical examination.

If an employee of the University that works in a laboratory meets any of the above conditions and would like medical consultation or examination, contact your campus Chemical Hygiene Officer for more information regarding the process to be followed for obtaining consultations or medical examinations.

All medical examinations and consultations will be performed by or under the direct supervision of a licensed physician to be determined by the University of Maine at Presque Isle. All examinations and consultations will be provided without cost to the affected employee. Monitoring results and/or written physician's statements will be provided to the employee by HR. Results of medical examinations or consultation must be considered confidential information.

The University of Maine at Presque Isle will provide the following information to the physician:

1. The identity of the hazardous chemical(s) to which the employee may have been exposed

2. A description of the conditions under which the exposure occurred including quantitative exposure data, if available.

3. A description of the signs and symptoms of exposure that the employee is experiencing, if any.

The University of Maine at Presque Isle will receive a written opinion from the examining physician which will include the following:

1. Any recommendation for further medical follow-up

2. The results of the medical examination and any associated tests.

3. Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous chemical found in the workplace.

4. A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that requires further examination or treatment.

The written opinion will not reveal specific findings of diagnoses unrelated to occupational exposure.

NOTE: THE PROCESS TO BE USED BY ANY EMPLOYEE AFFECTED BY THE ABOVE SHOULD BE STATED. THE CHEMICAL HYGIENE OFFICER SHOULD BE MADE AWARE OF THE SITUATION AND THE PROCESS SHOULD FOLLOW NORMAL WORKER'S COMPENSATION CHANNELS ESTABLISHED ON YOUR CAMPUS. CONTACT YOUR CAMPUS HUMAN RESOURCES OFFICE REGARDING WORKER'S COMPENSATION REPORTING.

CAMPUS CONTACTS

{29 CFR 1910.1450 (e)(3)(vii)

{FOR EMERGENCIES SEE EMERGENCY RESPONSE}

*Facilities Management –	207-768-9576
*Department and Chemical Hygiene Officer –	207-768-9450
*Safety and Security	207-768-9580
*National Response Center:	1-800-424-8802
*Off-hours campus emergency number	207-768-9600

EMPLOYEE INFORMATION AND TRAINING

A. INFORMATION

A copy of OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories; Final Rule (29 CFR 1910.1450) may be found in Appendix H. This institution's Chemical Hygiene Laboratory Safety Plan is available to all employees and may be found:

1. In any laboratory on campus
2. In departmental offices responsible for laboratories on campus
3. Through the campus Chemical Hygiene Officer

The permissible exposure limits for OSHA regulated substances can be found in appendix K. Recommended exposure limits for other hazardous substances, information on signs and symptoms associated with exposures to hazardous substances, and other information on the hazards, safe handling, and storage may be found on the substance's Safety Data Sheet (SDS) [formerly Material Safety Data Sheet (MSDS)] which are found in notebooks either in Facilities office or in science laboratories and chemical storage areas. SDSs are discussed in Appendix H. A list of select carcinogens, reproductive toxins, and substances of high acute toxicity are included in Appendix L.

B. TRAINING

University employees will be provided with training by the department responsible for the laboratory or area they are working in. This training is to ensure that they are apprised of the hazards of chemicals present in their work, how to obtain more information, and the standard operating and emergency procedures that should be used. Such training will be provided at the time of each employee's initial assignment to a work area where hazardous substances are present and if needed, prior to assignments involving new substances or exposure situations. Refresher training will also be provided at least annually. Instructors of laboratory courses will be provided with yearly training, and they will be responsible for safety training of their students. Employee training will include:

1. Methods and observations that may be used to detect the presence or release of hazardous substances.
2. The physical and health hazards of substances in the work area.
3. The measures employees can take to protect themselves from these hazards.
4. The applicable details of this Laboratory Safety Plan.
5. The location and availability of Safety Data Sheets/Material Safety Data Sheets (MSDSs) for hazardous substances in their work area.
6. Requirements and procedures for documentation of student safety training in laboratories by instructors.
7. Procedures for chemical inventory and hazardous waste disposal.

Laboratory Plan Training Documentation

Trainer ____________

Name	Date	Signature

Training included:

Individual Student Agreement Safety Forms and Laboratory Chemical Hygiene Information Sheets

1. Students should be trained in safety procedures on the first day of laboratories and they should check off the items on the agreement form and sign. Signed copies should be kept in notebooks in classroom laboratories.

2. Chemical Hygiene Information Sheets should be posted in all Laboratories.

Chemical Hygiene Information

University of Maine Presque Isle 2015

Folsom ___

Emergency Contacts

{FOR EMERGENCIES SEE EMERGENCY RESPONSE Guide in Laboratory Safety Plan}

*For immediate emergency service-	8-911
*Northern New England Poison Center:	1-800-222-1222
*Facilities Management –	207-768-9576
*Department and Chemical Hygiene Officer –	207-768-9450
*Campus Safety and Security	207-768-9580
*National Response Center:	1-800-424-8802

After Hours Contact:	
Name	Contact information
	Work/Office: Home: Cell:

General Laboratory Safety Guidelines:

- No food or drink in the laboratory at any time.
- Use protective clothing (gloves, lab coats, face masks, eye protection) whenever working with any hazardous chemical.
- Be familiar with the chemicals you use. Refer to Safety Data Sheets/Material Safety Datasheets records in your lab
- Use a fume hood for all hazardous gases, vapors, dusts or aerosols.
- Know the locations and uses of the nearest eyewash, shower, fire extinguisher, gas shutoffs, building escape route, first aid kit and spill kit.
- Store Chemicals in their proper places.
- Report any injury or spill to a science faculty member or your immediate supervisor, Facilities Management and the chemical safety officer.

FOLSOM 304 LABORATORY USE AGREEMENT
General Biology 113

PLACE A ✓ IN EACH ☐ BELOW AS YOU COMPLETE EACH PART.

EMERGENCY EQUIPMENT: I have located the following pieces of emergency and safety equipment and know how to use each of them:

☐ Emergency telephone and emergency telephone number list
☐ Dial 8-911 to call an ambulance or the fire department. (In the event of a health emergency, someone will stand outside to guide the ambulance to the building and classroom).
☐ UMPI Health Center: #9586
☐ Shower and eyewash station
☐ Eyewash bottles
☐ Fume hood
☐ Three chemical cleanup kits
☐ First aid kit
☐ Fire extinguisher
☐ Fire blanket
☐ Safety Notebook and notebook containing MSDS sheets for all chemicals in the room

SAFETY GUIDELINES: I understand and will follow the following guidelines:

☐ I will wear clothing and footwear that protects me (no open-toed shoes) and will not be destroyed by contact with laboratory materials, including safety glasses as recommended by the instructor.
☐ I will avoid wearing loose-fitting items of clothing. My extra clothing and outerwear will be placed on a side bench or table I am not using.
☐ I will keep my workspace free of unnecessary materials. My coat will be placed on a designated side bench. My backpack and books will be tucked away under the bench so they are not a hazard to me and other people moving about the lab. They will be placed on the side bench if they are in the way.
☐ I will not bring food or drinks into the laboratory room and will refrain from putting other objects in my mouth (including pens and pencils).
☐ I will put away and turn off my cell phone when I enter the lab.
☐ I will tie back shoulder length hair or longer to prevent ignition from open flames and contamination of laboratory materials.
☐ I will immediately report to the Science Department faculty member any spills, other accidents or mistakes with the equipment.
☐ I will follow instructions for disposal of all chemicals.
☐ I will <u>not</u> return unused chemicals to the stock bottles.
☐ I will wash reusable supplies and equipment and return them to the place designated by the instructor.
☐ I will dispose of broken glass in the yellow receptacle marked for this purpose.
☐ I will dispose of razor blades and sharp objects in the red biohazard receptacle.
☐ I will dispose of plant and animal materials in the trash barrel with the yellow lid.
☐ I will recycle paper products in the blue trash basket labeled “We Recycle.”
☐ I will dispose of all other solid waste in the green plastic trash basket.
☐ I will wash my hands with disinfectant soap at the sink before leaving the laboratory.

I have read, I understand and I agree to comply with the use of emergency equipment and safety guidelines and the use of the laboratory room stated above.

Signatures:

________________________________ __________________
Student Date

________________________________ __________________
Instructor Date
Department of Biology

FOLSOM 304 LABORATORY USE AGREEMENT
General Biology 112

PLACE A ✓ IN EACH ☐ BELOW AS YOU COMPLETE EACH PART.

EMERGENCY EQUIPMENT: I have located the following pieces of emergency and safety equipment and know how to use each of them:

☐ Emergency telephone and emergency telephone number list
☐ Dial 8-911 to call an ambulance or the fire department. (In the event of a health emergency, someone will stand outside to guide the ambulance to the building and classroom).
☐ UMPI Health Center: #9586
☐ Shower and eyewash station
☐ Eyewash bottles
☐ Fume hood
☐ Three chemical cleanup kits
☐ First aid kit
☐ Fire extinguisher
☐ Fire blanket
☐ Safety Notebook and notebook containing SDS sheets for all chemicals in the room

SAFETY GUIDELINES: I understand and will follow the following guidelines:

☐ I will wear clothing and footwear that protects me (no open-toed shoes) and will not be destroyed by contact with laboratory materials, including safety glasses as recommended by the instructor.
☐ I will avoid wearing loose-fitting items of clothing. My extra clothing and outerwear will be placed on a side bench or table I am not using or coat rack.
☐ I will keep my workspace free of unnecessary materials. My coat will be placed on a designated side bench or coat rack. My backpack and books will be tucked away under the bench so they are not a hazard to me and other people moving about the lab. They will be placed on the side bench if they are in the way.
☐ I will not bring food or drinks into the laboratory room and will refrain from putting other objects in my mouth (including pens and pencils).
☐ I will put away and turn off my cell phone when I enter the lab.
☐ I will tie back shoulder length hair or longer to prevent ignition from open flames and contamination of laboratory materials.
☐ I will immediately report to a Science Department faculty member any spills, other accidents or mistakes with the equipment.
☐ I will follow instructions for disposal of all chemicals.
☐ I will not return unused chemicals to the stock bottles.
☐ I will wash reusable supplies and equipment and return them to the place designated by the instructor.
☐ I will dispose of broken glass in the yellow receptacle marked for this purpose.
☐ I will dispose of razor blades and sharp objects in the red sharps receptacle.
☐ I will dispose of plant and animal materials in the trash barrel with the yellow lid.
☐ I will place biohazardous waste in red bags provided by instructor.
☐ I will recycle paper products in the blue trash basket labeled “We Recycle.”
☐ I will dispose of all other solid waste in the green plastic trash basket.
☐ I will wash my hands with disinfectant soap at the sink before leaving the laboratory.

I have read, I understand and I agree to comply with the use of emergency equipment and safety guidelines and the use of the laboratory room stated above.

Signatures:

________________________________ __________________
Student Date

________________________________ __________________
Instructor Date
Biology Dept.
University of Maine at Presque Isle

FOLSOM 305 LABORATORY USE AGREEMENT

Genetics/Microbiology/Vertebrate Biology

PLACE A ✓ IN EACH ☐ BELOW AS YOU COMPLETE EACH PART.

EMERGENCY EQUIPMENT: I have located the following pieces of emergency and safety equipment and know how to use each of them:

- ☐ Emergency telephone and emergency telephone number list
- ☐ Dial 8-911 to call an ambulance or the fire department. (In the event of a health emergency, someone will stand outside to guide the ambulance to the building and classroom).
- ☐ UMPI Health Center: #9586
- ☐ Shower and eyewash station
- ☐ Eyewash bottles
- ☐ Fume hood
- ☐ Three chemical cleanup kits
- ☐ First aid kit
- ☐ Fire extinguisher
- ☐ Fire blanket
- ☐ Safety Notebook and notebook containing MSDS sheets for all chemicals in the room

SAFETY GUIDELINES: I understand and will follow the following guidelines:

- ☐ I will wear clothing and footwear that protects me (no open-toed shoes) and will not be destroyed by contact with laboratory materials, including safety glasses as recommended by the instructor.
- ☐ I will avoid wearing loose-fitting items of clothing. My extra clothing and outerwear will be placed on a side bench or table I am not using.
- ☐ I will keep my workspace free of unnecessary materials. My coat will be placed on a designated side bench. My backpack and books will be tucked away under the bench so they are not a hazard to me and other people moving about the lab. They will be placed on the side bench if they are in the way.
- ☐ I will not bring food or drinks into the laboratory room and will refrain from putting other objects in my mouth (including pens and pencils).
- ☐ I will put away and turn off my cell phone when I enter the lab, unless instructed otherwise.
- ☐ I will tie back shoulder length hair or longer to prevent ignition from open flames and contamination of laboratory materials.
- ☐ I will immediately report to a Science Department faculty member any spills, other accidents or mistakes with the equipment.
- ☐ I will carefully follow instructions for disposal of all chemicals.
- ☐ I will not return unused chemicals to the stock bottles.
- ☐ I will carefully follow instructions for the use of all equipment, with particular attention to electrophoresis chambers that generate voltage.
- ☐ I will wash reusable supplies and equipment and return them to the place designated by the instructor.
- ☐ I will dispose of broken glass in the yellow receptacle marked for this purpose.
- ☐ I will dispose of razor blades and sharp objects in the red biohazard receptacle.
- ☐ I will dispose of plant and animal materials in the trash barrel with the yellow lid.
- ☐ I will recycle paper products in the blue trash basket labeled “We Recycle.”
- ☐ I will dispose of materials designated as biohazardous in the biohazard bags or counter area to be autoclaved.
- ☐ I will dispose of all other solid waste in the green plastic trash basket.
- ☐ I will wash my hands with disinfectant soap at the sink before leaving the laboratory.

I have read, I understand and I agree to comply with the use of emergency equipment and safety guidelines and the use of the laboratory room stated above.

Signatures:

_______________________________ _________________
Student Date

_______________________________ _________________
Instructor Date

FOLSOM 202 LABORATORY USE AGREEMENT
Biochemistry BIO 327

PLACE A ✓ IN EACH ☐ BELOW AS YOU COMPLETE EACH PART.

EMERGENCY EQUIPMENT: I have located the following pieces of emergency and safety equipment and know how to use each of them:

☐ Emergency telephone and emergency telephone number list
☐ Dial 8-911 to call an ambulance or the fire department. (In the event of a health emergency, someone will stand outside to guide the ambulance to the building and classroom).
☐ UMPI Health Center: #9586
☐ Shower and eyewash station
☐ Eyewash bottles
☐ Fume hood
☐ Three chemical cleanup kits
☐ First aid kit
☐ Fire extinguisher
☐ Fire blanket
☐ Safety Notebook and notebook containing MSDS sheets for all chemicals in the room

SAFETY GUIDELINES: I understand and will follow the following guidelines:

☐ I will wear clothing and footwear that protects me (no open-toed shoes) and will not be destroyed by contact with laboratory materials.
☐ I will wear safety glasses at all times while in the laboratory.
☐ I will avoid wearing loose-fitting items of clothing. My extra clothing and outerwear will be placed on a side bench or table I am not using.
☐ I will keep my workspace free of unnecessary materials. My coat will be placed on a designated side bench. My backpack and books will be placed on a side bench so they are not a hazard to me and other people moving about the lab. My notebooks will be kept on the bench and not sticking out for others to bump into.
☐ I will not bring food or drinks into the laboratory room and will refrain from putting other objects in my mouth (including pens and pencils).
☐ I will put away and turn off my cell phone when I enter the lab.
☐ I will tie back shoulder length hair or longer to prevent ignition from open flames and contamination of laboratory materials.
☐ I will use caution when using electrical equipment and follow instructions of the instructor for their use.
☐ I will immediately report to a Science Department faculty member any spills, other accidents or mistakes with the equipment.
☐ I will carefully dispense chemicals from stock bottles, placing only clean items in to retrieve chemicals to avoid contamination. I will <u>not</u> return unused chemicals to the stock bottles.
☐ I will carefully follow instructions for disposal of all chemicals.
☐ I will <u>not</u> return unused chemicals to the stock bottles.
☐ I will wash reusable supplies and equipment and return them to the place designated by the instructor.
☐ I will clean and return all of my assigned items to my assigned drawer and lock the drawer before leaving.
☐ I will dispose of broken glass in the trash barrel marked for this purpose.
☐ I will dispose of razor blades and sharp objects in the red biohazard receptacle.
☐ I will dispose of all other solid waste in the trash baskets.
☐ I will wash my hands with disinfectant soap at the sink before leaving the laboratory.

I have read, I understand and I agree to comply with the use of emergency equipment and safety guidelines and the use of the laboratory room stated above.

Signatures:

_______________________________ _________________
Student Date

_______________________________ _________________
Instructor Date

LABORATORY SAFETY PLAN

REVIEW AND UPDATE

{29 CFR 1910.1450 (e)(4)}

This Laboratory Safety Plan will be reviewed annually by the campus Chemical Hygiene Officer or his/her designee will also review this document at least annually to ensure it is being used effectively and updated as required by those responsible for this laboratory.

DATEREVIEWERUPDATED (Y/N)

Date	**Reviewer**	**Updated**	**Y/N**

GENERAL EMERGENCY PROCEDURES

The following emergency procedures are recommended in the event of fire, explosion, or other laboratory accident. These procedures are intended to limit injuries and minimize damage if an accident should occur. See Appendix A for more information about Chemical Spills.

FIRE OR EXPLOSION

1. Render assistance to persons involved and remove them from exposure to further injury if necessary.

2. Warn personnel in adjacent areas of any potential hazards to their safety or sound building alarm.

3. Render immediate first aid; appropriate measures include washing under a safety shower, administering oxygen and artificial resuscitation if breathing has stopped, and special first aid measures (such as the use of a cyanide first aid kit if cyanide exposure in involved).

4. Extinguish small fires by using a portable extinguisher only if you have been trained in its use.

5. Turn off nearby apparatus and remove combustible materials from the area.

6. In case of larger fires, sound building alarm and contact the appropriate fire department promptly.

In case of medical emergency, laboratory personnel should remain calm and do only what is necessary to protect life.

MEDICAL EMERGENCY

1. Summon medical help immediately.

2. Do not move an injured person unless he or she is in danger of further harm.

3. Keep any injured person warm. If feasible, designate one person to remain with the injured person. The injured person should be within sight, sound, or physical contact of that person at all times.

4. If clothing is on fire, knock the person to the floor and roll him or her around to smother the flames or, if a safety shower is immediately available, douse the person with water.

5. If chemicals have been spilled on the body, flood the exposed area with sufficient running water from the safety shower and immediately remove any contaminated clothing.

6. If a chemical has entered the eye, immediately wash the eyeball and the inner surface of the eyelid with plenty of water for 15 min. An eyewash fountain should be used if available. Forcibly hold the eye open to wash thoroughly behind eyelids.

PREPARING FOR EMERGENCIES

Each department responsible for laboratories must ensure that a specific emergency plan is established for each laboratory or facility. Such a plan should include evacuation routes and shelter areas, medical facilities, and procedures for reporting all accidents and emergencies and should be reinforced by frequent drills and simulated emergencies. The specific plan for your laboratory should be found in the individual lab plans. Emergency telephone numbers for your laboratory should be found in Appendix Z.

EVACUATION PROCEDURES

Evacuation procedures should be established and communicated to all personnel working in and around laboratory facilities.

Emergency alarm system

1. A system should be available to alert personnel in the event of an emergency that may require evacuation. Laboratory personnel should be familiar with the location and operation of this equipment.

2. A system should be established to relay telephone alert messages; the names and telephone numbers of personnel responsible for each laboratory or other area should be prominently posted in case of emergencies outside regular working hours (See Appendix Z).

3. Isolation areas (*e.g.*, cold, warm, or sterile rooms) should be equipped with alarm or telephone systems that can be used to alert outsiders to the presence of a worker trapped inside or to warn workers inside of the existence of an emergency outside that requires their evacuation.

4. Where unusually toxic substances are handled, it may be desirable to have a monitoring and alarm system so that, if the concentration of the substances in the work environment exceeds a set limit, an alarm is sounded to warn the laboratory workers to evacuate the area.

Evacuation procedures

1. Evacuation routes and alternatives may need to be established and, if so, should be communicated to all personnel (See individual lab plans). An outside assembly area for evacuated personnel should be designated.

Shutdown procedures

1. Brief guidelines for shutting down operations during an emergency or evacuation should be communicated to all personnel (See individual lab plans).

Return and start-up procedures

1. Return procedures to ensure that personnel do not return to the laboratory until the emergency is ended and start-up procedures that may be required for some operations should be prominently displayed and reviewed regularly.

Drills

1. All aspects of the emergency procedure should be tested regularly (*e.g.*, every 6 months to a year), and trials of evacuations (if there are such procedures) should be held periodically.

MEDICAL FACILITIES

Laboratories that do not have a regular medical staff should have personnel trained in first aid available during regular working hours to render assistance until medical help can be obtained.

An emergency room staffed with medical personnel specifically trained in proper treatment of chemical exposure should be readily accessible. For small laboratories, prior arrangement with a nearby hospital or emergency room may be necessary to ensure that treatment will be available promptly. The services of an ophthalmologist especially alerted to and familiar with chemical injury treatment should also be available to minimize the damage to eyes that may result from many types of laboratory incidents. Proper and speedy transportation of the injured to the medical treatment facility should be available. In addition to the normal facilities found in an emergency room, there should be special provisions that include specific standing orders for emergency treatment of chemical accidents. Emergencies that should be anticipated include the following:

1. thermal and chemical burns
2. cuts and puncture wounds from glass or metal, including possible chemical contamination
3. skin irritation by chemicals
4. poisoning by ingestion, inhalation, or skin absorption
5. asphyxiation (chemical or electrical)

6. injuries to the eyes from splashed chemicals.

ACCIDENT AND EMERGENCY REPORTING

All accidents and emergency must be promptly reported to both the Department Chairperson ultimately responsible for your laboratory and to your campus chemical hygiene officer. Such reports are required by law in many cases and help to uncover hazards that can be corrected. In all cases, the report should be in a written form and retained. The campus chemical hygiene officer will send a copy of any and all reports to the System's Office of Facilities in Bangor.

FIRES AND EXPLOSIONS

Small fires that can easily be extinguished without evacuating the building or calling the fire department and are among the most common laboratory incidents. However, even a minor fire can quickly become a serious problem. The first few minutes after discovery of a fire are critical in preventing a larger emergency. The following actions should be taken by laboratory personnel in case of a minor fire:

1. Alert other personnel in the laboratory and send someone for assistance.

2. If you have the means and have be trained, attack the fire immediately, but never attempt to fight a fire alone. A fire in a small vessel can often be suffocated by covering the vessel with an inverted beaker or a watch glass.

3. Use the proper extinguisher, directing the discharge of the extinguisher at the base of the flame. To ensure that the proper type of extinguisher is used, compare its use label with the descriptions below.

Class A fires--ordinary combustible solids such as paper, wood, coal, rubber, and textiles

Class B fires--petroleum hydrocarbons (diesel fuel, motor oil, and grease) and volatile flammable solvents

Class C fires--electrical equipment

Class D Fires--combustible or reactive metals (such as sodium and potassium, metal hydrides, or organometallics (such as alkylaluminims).

4. Avoid entrapment in a fire; always fight a fire from a position accessible to an exit.

If there is any doubt whether the fire can be controlled by locally available personnel and equipment, the following actions should be taken:

1. Notify the fire department and activate the emergency alarm system.

2. Confine the emergency (close hood sashes, doors between laboratories, and fire doors) to prevent further spread of the fire.

3. Assist injured personnel (provide first aid or transportation to medical aid if necessary).

4. Evacuate the building to avoid further danger to personnel.

In case of an explosion, immediately turn off burners and other heating devices, stop any reactions in progress, assist in treating victims, and vacate the area until it has been decontaminated.

The laboratory supervisor is responsible for determining whether unusual hazards exist that require more stringent safety precautions. In large laboratories, or where risk is high, designated firefighting teams may be necessary to minimize risk. Special arrangements with local fire departments to warn them of the hazards of chemical fires may be desirable in some situations.

CHEMICAL SPILLS **(Also found as Appendix A-11 and A-12)**

Small-scale spills may cleaned up using anything from a mop and a bucket to an emergency response team. What is needed is very dependent on the substance(s) spilled. Pre-planning should occur prior to the handling of any substance in the laboratory to help minimize exposure to laboratory personnel and equipment. The best way to plan is to consider the possibility of a spill and outline the steps you would need to take to clean it up. For most small-scale laboratory spills, the following considerations should be evaluated when developing clean up procedures to be used prior to the handling of any material.

1. The potential locations of spills (e.g. outdoors vs. indoors, laboratory, corridor, storage area, table, in hood, on floor) when developing spill plans.

2. The potential quantity of the material that may be released when developing spill plans.

3. The chemical and physical properties (e.g. physical state, vapor pressure, reactivity) of the material(s) that may be released when developing spill plans.

4. The hazardous properties of materials (e.g. toxicity, corrosivity, flammability).

5. The types of personal protective equipment (apparel, respiratory protections, etc.) that might be needed.

Supplies needed to clean up small-scale spills should always be available. Examples would be neutralizing agents, absorbents, gloves, and specialized spill kits.

If a spill occurs (if mercury, see Appendix A-12 Small-Scale Mercury Spill Response Plan):

1. Attend to persons who may have been contaminated.

2. Notify persons in the immediate area about the spill.

3. Evacuate all nonessential personnel from the spill area.

4. If the spill is flammable, turn off ignition and heat sources (from outside of the area such as a circuit breaker).

5. Avoid breathing vapors (use a respirator if necessary, but only if trained to do so). If not trained in respirator use and one is needed, evacuate the area and inform Facilities and call for help.

6. Leave on or establish exhaust ventilation if safe to do so.

7. Secure proper supplies to effect cleanup.

8. During cleanup, wear appropriate apparel.

9. Notify Facilities Management and campus chemical hygiene officer if a regulated substance is involved.

10. Log the spill in the Spill Log provided in each laboratory.

HANDLING OF SPILLED LIQUIDS

1. Confine or contain. Do not let the substance spread.

2. For small quantities of inorganic acids or bases, use neutralizing agent or absorbent mixture.

3. For small quantities of other materials absorb with nonreactive material.

4. For larger amounts, flush with large quantities of water (providing it will not cause additional damage).

5. Mop up spill with mop requested from Facilities, wring out mop in sink or pail equipped with rollers. Mop should be considered contaminated and treated as hazardous waste.

6. Pick up and clean any cartons or bottles that have been splashed or immersed.

7. Vacuum area with a vacuum approved for use with material involved- a HEPA-equipped Vacuum.

8. Dispose of residues and clean up equipment according to safe disposal procedures.
9. Log the spill in the Spill Log provided in each laboratory.

HANDLING OF SPILLED SOLIDS

1. If substance is of low toxicity, sweeping and placing material in a solid waste container for proper disposal is acceptable.

2. May also use a vacuum equipped with a HEPA filtration system.

HANDLING OF LEAKING COMPRESSED GAS CYLINDERS

Usually leaks in compressed gas cylinders occur mainly around the valve mechanisms. Never use a flame to detect leaks. Use a leak detector specific for the leaking gas or use soapy water. If you are unable to fix a leaking compressed gas cylinder by tightening, emergency procedures should be used and the supplier contacted. If you are moving a leaking tank out of a building, cover tank with a bag and tape to help confine the gas. Some specific considerations:

1. Flammable, oxidizing, or inert gas - move to an isolated area away from combustible materials and post appropriate warning signs.

2. Corrosive gases may increase the size of the leak - move to an isolated, well ventilated area. Attempt to direct the gas towards a neutralizer. Post warning signs.

3. Toxic gases - move to an isolated, well ventilated area. Attempt to direct the gas towards a neutralizer. Post warning signs.

The use of self-contained breathing apparatus may be necessary due to the nature of the gas and the size of the leak.

When large-scale spills may be possible, emergency procedures should be prepared for containing spilled chemicals with minimal damage. A spill-control policy should include consideration of the following points:

1. *prevention*--storage, operating procedures, monitoring, inspection, and personnel training;

2. *containment*--engineering controls on storage facilities and equipment;

3. *cleanup*--countermeasures and training of designated personnel to help reduce the impact of a chemical spill; and

4. *reporting*--provisions for reporting spills both internally (to identify controllable hazards) and externally (for example, to state and federal regulatory agencies).

OTHER EMERGENCIES

Laboratories should be prepared for hazards resulting from loss of any utility service or severe weather. Loss of the water supply, for example, can render safety showers, eyewash fountains, and sprinkler systems inoperative. All hazardous laboratory work should cease until service is restored.

FIRST AID

First aid is the immediate care of a person who has been injured or has suddenly taken ill. It is intended to prevent death or further illness and injury and to relieve pain until medical aid can be obtained. The objectives of first aid are:

(1) to control conditions that might endanger life
(2) to prevent further injury
(3) to relieve pain, prevent contamination, and treat for shock
(4) to make the patient as comfortable as possible.

The initial responsibility for first aid rests with the first person(s) at the scene, who should react quickly but in a calm and reassuring manner. The person assuming responsibility should immediately summon medical help (be explicit in reporting suspected types of injury or illness and requesting assistance). The injured person should not be moved except where necessary to prevent further injury. Laboratory workers should be encouraged to obtain training in first aid and cardiopulmonary resuscitation (CPR).

PULMONARY RESUSCITATION

If the patient is unresponsive and no breathing movements are apparent, begin mouth-to-mouth resuscitation immediately. Delay increases the risk of serious disability or death.

1. Place the patient flat on his or her back on the floor and kneel at the side.

2. Establish an airway. Check the patient's mouth with your finger to be sure that no obstruction is present and then tip the patient's head back until the chin points straight up.

3. Pinch the patient's nostrils, and begin mouth-to-mouth resuscitation by taking a deep breath and placing your mouth over the patient’s mouth so as to make a leak-proof seal.

4. Blow your breath into the patient`s mouth until you see the chest rise.

5. Remove your mouth and allow the patient to exhale.

6. Repeat the procedure at a rate of once every 5 seconds.

HEART (CARDIAC) RESUSCITATION

In the unresponsive patient, check for a cardiac pulse; locate the larynx or adam's apple with the tips of the fingers and slide them into the groove between it and the muscle at the side of the neck. If no pulse is felt, circulation must be reestablished within 4 min to prevent brain damage.

1. With the patient flat on his or her back, kneel at the waist, facing the head.

2. Place the heel of your right hand over the heel of your left hand on top of the patient's breastbone about 3 cm above its lower tip.

3. Shift your weight to the patient's chest and compress it at least 4 cm, then remove the pressure.

4. Continue at a rate of 80 times/min.

HEAVY BLEEDING

Heavy bleeding is caused by injury to one or more large blood vessels. Lay the patient down. Control bleeding by applying firm pressure directly over the wound with a clean handkerchief, cloth, or your hand. A tourniquet should be applied only in cases of an amputation or other injury to a limb in which there is no other way to stop the bleeding. If tourniquet is used, a record of the time it was applied must be kept.

SHOCK

Shock usually accompanies severe injury. The signs of shock include pallor, a cold and clammy skin and beads of perspiration on the forehead and palms or hands, weakness, nausea or vomiting, shallow breathing, and a rapid pulse that may be too faint to be felt at the wrist. The following procedures for the treatment of shock should be followed:

1. Correct the cause, if possible (*e.g.*, control bleeding).

2. Keep the patient lying down; if there are no contraindications (*e.g.*, a head injury), elevate the patient's legs.

3. Keep the patient's airway open. If he or she is about to vomit, turn the head to the side.

4. Keep the patient warm.

MISCELLANEOUS ILLNESSES AND INJURIES

After requesting medical aid, the following points should be addressed in specific emergencies:

1. *Abdominal pain* - Keep the patient quiet. Give nothing by mouth.

2. *Back and neck injuries* - Keep the patient absolutely quiet. Do not move the patient or lift the head unless absolutely necessary.

3. *Chest pain* - Keep the patient calm and quiet. Place the patient in the most comfortable position (usually half sitting).

4. *Convulsion or epileptic seizure* - Place the patient on the floor or a couch. **Do not** restrain the patient's movements except to prevent injury. **Do not** place a blunt object between the teeth. **Do not** place any liquid in the mouth, or slap the patient or douse him or her with water.

5. *Electric Shock* - Throw the switch to turn off the current. **Do not** touch the victim until he or she is separated from the current source. Begin mouth-to-mouth resuscitation if respiration has ceased.

6. *Fainting* - Simple fainting can usually be reversed quickly by laying the victim down.

7. *Unexplained unconsciousness* - Look for emergency medical identification around the victim's neck or wrist or his or her wallet. Keep the victim warm, lying down, and quiet until he or she regains consciousness. Do not move the victim's head if there is bleeding from the nose, mouth, ear, or eyes. Do not give the victim anything by mouth. Keep the victim's airway open to aid breathing. Do not cramp the neck with a pillow.

CHEMICAL INGESTION OR CONTAMINATION

Ingestion of Chemicals

Attempt to learn exactly what substances were ingested, refer to the SDS available in a notebook in each laboratory and inform the medical staff (while the victim is en route, if possible) and the local poison control center. If possible, fax or send the SDS electronically ahead.

Chemicals Spilled on the Body over a Large Area

Quickly remove all contaminated clothing while using the safety shower; seconds count and not a minute should be wasted because of modesty. Immediately flood the affected body area with cold water for at least 15 min; resume if pain returns. Wash off chemicals by using a mild detergent or soap (preferred) and water; do not use neutralizing chemicals, unguents, or salves.

Chemicals on the Skin in a Confined Area

Immediately flush with cold water and wash by using a mild detergent or soap (preferred) and water. If there is no visible burn, scrub with warm water and soap, removing any jewelry in the affected area. If a delayed action [the physiological effects of some chemicals (*e.g.*, methyl and ethyl bromides) may be delayed as much as 48 hours] is noted, obtain medical attention promptly and explain carefully what chemicals were involved.

STANDARD OPERATING PROCEDURES

Appendix A. The laboratory operating procedures found in Prudent Practices for Handling Hazardous Chemicals in Laboratories (National Research Council, 1981) have been generally adopted for use by the University of Maine at Presque Isle. The following topics have been extracted and adapted and are found in Appendix A. These are relevant to activities conducted in this laboratory.

A-1 General Procedures for Safe Laboratory Practice
A-2 Protective Apparel for the Laboratory
A-3 Safety Equipment for the Laboratory
A-4 Electrical Equipment in the Laboratory
A-5 Working with Acutely Toxic, Chronically Toxic and Corrosive Substances
A-6 Handling Flammable and Explosive Substances
A-7 Ordering and Procurement of Chemicals
A-8 Storing Chemicals in Storerooms or Stockrooms
A-9 Distributing Chemicals from Stockrooms to Laboratories
A-10 Storing Chemicals in Laboratories
A-11 Handling Spills
A-12 Small-Scale Mercury Spill Response Procedure
A-13 High and Low Pressure Experiments
A-14 Handling of Compressed Gases

Appendix B. Center for Disease Control (CDC) Guidelines for work using infectious agents and managing biohazardous waste are incorporated by reference into this laboratory safety plan.
http://www.cdc.gov/biosafety/publications/bmbl5/BMBL5_sect_IV.pdf

Appendix D: Use and Types of Laboratory Hoods

Appendix E: Testing Procedures for Certification of Laboratory Fume Hoods

Appendix F: Semi-annual Preventative Maintenance Plan for Laboratory Fume Hoods.

Appendix G: Recommendations for New Laboratory Hoods

Appendix H: University of Maine at Presque Isle Hazard Communication Program

Appendix L: Lists of select carcinogens and substances of high toxicity

Appendix Z: Emergency Phone Contacts

Appendix A-1

GENERAL PROCEDURES FOR SAFE LABORATORY PRACTICE

The following has been extracted and adapted from Prudent Practices for Handling Hazardous Chemicals in Laboratories (National Research Council, 1981), Chapter IA.

I. GENERAL PRINCIPLES

Every laboratory worker should observe the following rules:

1. Know the safety rules and procedures that apply to the work that is being done. Determine the potential hazards (eg. physical, chemical, biological) and appropriate safety precautions before beginning any new operation.

2. Know the location of and how to use the emergency equipment in your area, as well as how to obtain additional help in an emergency, and be familiar with emergency procedures.

3. Know the types of protective equipment available and use the proper type for each job.

4. Be alert to unsafe conditions and actions and call attention to them so that corrections can be made as soon as possible. Someone else's accident can be as dangerous to you as any you might have.

5. Avoid consuming food or beverages or smoking in areas where hazardous substances (eg. chemicals, biologicals) are being used or stored.

6. Avoid hazards to the environment by following accepted waste disposal procedures. Chemical reactions may require traps or scrubbing devices to prevent the escape of toxic substances.

7. Be certain all chemicals are correctly and clearly labeled as required by the campus Hazard Communication Program. Post warning signs when unusual hazards, such as radiation, laser operations, flammable materials, biological hazards, or other special activities exist.

8. Remain out of the area of a fire or personal injury unless it is your responsibility to help meet the emergency. Curious bystanders interfere with rescue and emergency personnel and endanger themselves.

9. Avoid distracting or startling any other worker. Practical jokes or horseplay cannot be tolerated at any time in the laboratory.

10. Use equipment only for its designated purpose.

11. Setup and position reaction apparatus and equipment thoughtfully in order to permit manipulation without the need to move the apparatus until the entire reaction or process is completed.

12. Think, act, and encourage safety until it becomes habit.

II. HEALTH AND HYGIENE

Laboratory workers should observe the following health practices:

1. Wear appropriate eye protection at all times.

2. Use protective apparel, including face shields, gloves, and other special clothing or footwear as needed.

3. Confine long hair and loose clothing when in the laboratory.

4. Do not use mouth suction to pipet chemicals or to start a siphon; a pipet bulb or an aspirator should be used to provide vacuum.

5. Avoid exposure to gases, vapors, and aerosols. Use appropriate safety equipment whenever such exposure is likely.

6. Wash well before leaving the laboratory area. However, avoid the use of solvents for washing skin. They remove the natural protective oils from the skin and can cause irritation and inflammation. In some cases, washing with a solvent might facilitate absorption of a toxic chemical.

III. FOOD HANDLING

Contamination of food, drink, and smoking materials is a potential route for exposure to toxic substances. Food should be stored, handled, and consumed in an area free of hazardous substances.

1. Well-defined areas should be established and used for storage and consumption of food and beverages. No food should be stored or consumed outside of this area.

2. Areas where food is permitted should be prominently marked and a warning sign (e.g. EATING AREA-NO CHEMICALS) posted. No chemicals or chemical equipment should be allowed in such areas.

3. Consumption of food or beverages and smoking should not be permitted in areas where laboratory operations or storage of hazardous substances are being carried out.

4. Glassware or utensils that are designated for use in laboratory operations should never be used to prepare or consume food or beverages. Laboratory refrigerators, ice chests, cold rooms, and such should not be used for food storage; separate equipment should be dedicated to that use and prominently labeled.

IV. HOUSEKEEPING

There is a clear relationship between safety performance and orderliness in the laboratory. When housekeeping standards fall, safety performance inevitably deteriorates. The work area should be kept clean, and chemicals and equipment should be properly labeled and stored.

1. Work areas should be kept clean and free from obstructions. Cleanup should follow the completion of any operation or at the end of each day.

2. Wastes should be deposited in appropriate receptacles.

3. Spilled chemicals should be cleaned up immediately and disposed of properly. Follow established disposal procedures; the effects of other laboratory accidents should be cleaned up promptly.

4. Unlabeled containers and chemical wastes should be disposed of promptly, by using appropriate procedures. Such materials, as well as chemicals that are no longer needed, should not accumulate in the laboratory.

5. Floors should be cleaned regularly; accumulated dust, chromatography adsorbents, and other assorted chemicals pose respiratory hazards.

6. Stairways and hallways should not be used as storage areas.

7. Access to exits, emergency equipment, controls, and such should never be blocked.

8. Equipment and chemicals should be stored properly; clutter should be minimized.

V. EQUIPMENT MAINTENANCE

Good equipment maintenance is important for safe, efficient operations. Equipment should be inspected and maintained regularly. Servicing schedules will depend on both the possibilities and the consequences of failure. Maintenance plans should include a procedure to ensure that a device is out of service and cannot be restarted.

VI. GUARDING FOR SAFETY

All mechanical equipment should be adequately furnished with guards that prevent access to electrical connections or moving parts (such as the belts and pulleys of a vacuum pump). Each laboratory worker should inspect equipment before using it to ensure that the guards are in place and functioning. If guards are missing or not in place, equipment shall be taken out of service until repaired or fitted with a guard.

VII. SHIELDING FOR SAFETY

1. Safety shielding should be used for any operation having the potential for explosion such as:

(a) whenever a reaction is attempted for the first time (small quantities should be used to minimize hazards)

(b) whenever a familiar reaction is carried out on a larger than usual scale

(c) whenever operations are carried out under non-ambient conditions.

2. Shields must be placed so that all personnel in the area are protected from hazard.

VIII. GLASSWARE

Accidents involving glassware are a leading cause of laboratory injuries.

1. Careful handling and storage procedures should be used to avoid damaging glassware. Damaged items should be discarded or repaired.

2. Adequate hand protection should be used when inserting glass tubing into rubber stoppers or corks or when placing rubber tubing on glass hose connections. Tubing should be fire polished or rounded and lubricated, and hands should be held close together to limit movement of glass should fracture occur. The use of plastic or metal connectors should be considered.

3. Glass-blowing operations should not be attempted unless proper annealing facilities are available.

4. Vacuum-jacketed glass apparatus should be handled with extreme care to prevent implosions. Equipment such as Dewar flasks should be taped or shielded. Only glassware designed for vacuum work should be used for that purpose.

5. Hand protection should be used when picking up broken glass. (Small pieces should be swept up with a brush into a dustpan).

6. Proper instruction should be provided in the use of glass equipment designed for specialized tasks, which can represent unusual risks for the first-time user. (For example, separatory funnels containing volatile solvents can develop considerable pressure during use).

IX. FLAMMABILITY HAZARDS

Since flammable materials are widely used in laboratory operations, the following rules should be observed:

1. Do not use an open flame to heat a flammable liquid or carry out a distillation under reduced pressure.

2. Use an open flame only when necessary and extinguish it when it is no longer actually needed.

3. Before lighting a flame, remove all flammable substances from the immediate area. Check all containers of flammable materials in the area to ensure that they are tightly closed.

4. Notify other occupants of the laboratory in advance of lighting a flame.

5. Store flammable materials properly.

6. When volatile flammable materials may be present, use only nonsparking electrical equipment. (If you are unsure about any particular piece of equipment being nonsparking, do not use it).

X. SYSTEMS UNDER PRESSURE

Reactions should never be carried out in, not heat applied to, an apparatus that is a closed system unless it is designed and tested to withstand pressure. Pressurized apparatus should have an appropriate relief device. If the reaction cannot be opened directly to the air, and inert gas purge and bubbler system should be used to avoid pressure buildup.

XI. WASTE DISPOSAL PROCEDURES

Established campus hazardous waste disposal procedures for routine and emergency situations may be found in the Hazardous Waste Disposal Program. Laboratory workers should follow these procedures with care, to avoid any safety hazards or damage to the environment.

XII. WARNING SIGNS AND LABELS

1. Laboratory areas that have special or unusual hazards should be posted with warning signs. Standard signs and symbols have been established for a number of special situations, such as radioactivity hazards, biological hazards, fire hazards, and laser operations. Other signs should be posted to show locations of safety showers, eyewash stations, exits, and fire extinguishers. Extinguishers should be labeled for the type of fire for which they are intended. Waste containers should be labeled for the type of waste that can be safely deposited.

2. The safety and hazard sign system in the laboratory should enable any person unfamiliar with the usual routine of the laboratory to escape in an emergency (or help combat it, if appropriate)

3. Labels on containers of chemicals or chemical mixtures should contain information on the hazards associated with use of the chemicals. A standardized secondary labeling system has been established in the campus Hazard Communication Program. A copy of this program is included in this plan, consult it or the campus chemical information coordinator.

4. Unlabeled bottles of chemicals should not be opened; such materials should be disposed of promptly and will require special handling procedures.

XIII. UNATTENDED OPERATIONS

1. Frequently, laboratory operations are carried out continuously or overnight. Planning for interruptions in utility services such as electricity, water, and inert gas is essential. Operations should be designed to be safe and plans should be made to avoid hazards in case of failure.

2. Arrangements for routine inspection of the operation should be made and, **in all cases,** the laboratory lights be left on and an appropriate sign should be placed on the door. The sign must indicate that a continuous operation is occurring and list name and telephone numbers of those familiar with operation in case an emergency or problem arises.

XIV. WORKING ALONE

1. Generally, it is prudent to avoid working alone in a laboratory building.

2. Under normal working conditions, arrangements should be made between individuals working in separate laboratories outside working hours to crosscheck periodically.

3. Any individual working alone should receive departmental permission prior to the occurrence. The department must notify campus police or security (to arrange for periodic checks on the person). The campus Chemical Hygiene Officer must be notified of the situation in writing prior to its occurrence.

4. Under unusual conditions, special rules may be necessary. The supervisor of the laboratory has the responsibility of determining whether the work requires special safety precautions, such as having two persons in the same room during a particular operation. Specific safety precautions must be in writing and submitted to the campus chemical hygiene officer for approval. Once approved it must be included in this laboratory safety plan in the Special Procedures appendix.

XV. ACCIDENT REPORTING

1. Emergency telephone numbers to be called in the event of fire, accident, flood, or hazardous chemical spill should be posted prominently in the laboratory. A copy of this information for this laboratory may be found in Appendix Z.

2. The numbers of the laboratory workers and their supervisors should also be prominently posted. These persons should be notified immediately in the event of an accident or emergency.

3. All incidents (accidents, injuries, spills), whether major or minor, must be reported to the laboratory supervisor. The laboratory supervisor will forward a copy of such reports to the campus chemical hygiene officer. This internal reporting system will be used to help identify and correct any unexpected hazards in the laboratory. The chemical hygiene officer will have the incident investigated with the goal being to make recommendations to improve safety, not to assign blame. Your assistance in reporting incidents is encouraged.

XVI. EVERYDAY HAZARDS

Finally, remember that injuries can and do occur outside the laboratory or work area. Practicing safety in offices, stairways, corridors, and other places is important. Here, safety is largely a matter of common sense, but a constant safety awareness of everyday hazards is vital.

Appendix A-2

Protective Apparel for the Laboratory

(extracted from: http://www.wpi.edu/offices/safety/hygiene.html and edited)

PERSONAL PROTECTIVE EQUIPMENT (PPE)

A variety of specialized clothing and equipment is commercially available for use in the laboratory. The proper use of these items will minimize or eliminate exposure to the hazards associated with many laboratory operations. Every laboratory worker should be familiar with the location and proper use of the PPE in their laboratory area.

The following are general guidelines on the proper use of safety equipment:

GENERAL EYE PROTECTION POLICY

Eye protection is required of all personnel and any visitors present in any location where chemicals are stored or handled. **No one should enter any laboratory without appropriate eye protection.** This protection should meet the requirements of the American National Standards Institute (ANSI) Z87.1. Safety spectacles that meet the criteria described below provide minimum eye protection for regular use. Additional protection may be required when carrying out more hazardous operations.

Contact lenses should not be worn in a laboratory. Gases and vapors can be concentrated under such lenses and cause permanent eye damage. Furthermore, in the event of a chemical splash in the eye, it is often nearly impossible to remove the contact lens to irrigate the eye because of involuntary spasm of the eyelid. There are some exceptional situations in which contact lenses must be worn for therapeutic reasons. Persons who must wear contact lenses should inform the laboratory supervisor so that satisfactory safety precautions can be devised.

SAFETY GLASSES

Ordinary prescription glasses do not provide adequate protection from injury to the eyes. Safety glasses must be worn to protect the eyes from the impact of flying objects, and some extent chemical splashes. When safety glasses are worn without sideshields, liquid splashes or flying particles can potentially reach the eye. If sideshields are attached to the frames, greater protection against liquid or solid agents is afforded.

GOGGLES

Goggles provide greater protection against chemical splashes than safety glasses with sideshields due to the fact that they fit more closely to the face and form a more effective barrier against foreign materials. Goggles are also impact-resistant.

GOGGLES WITH FACESHIELD

Faceshields provide good protection to the eyes, face and neck against flying particles, sprays of hazardous liquids, splashes of molten metal and hot solutions. They are not recommended for eye protection against the impact of hurtling objects, therefore it is generally necessary to wear safety glasses or goggles underneath the faceshield.

SPECIALIZED EYE PROTECTION

There are specific goggles and masks for protection against laser and ultraviolet light hazards, and other intense light sources, as well as glass blowing goggles, and welding masks and goggles. The laboratory supervisor should determine whether the task being performed requires specialized eye protection and require the use of such equipment if it is necessary.

GLOVES

Proper protective gloves should be worn whenever the potential for contact with corrosive or toxic materials and materials of unknown toxicity exists. Gloves should be selected on the basis of the material being handled, the particular hazard involved, and their suitability for the operation being conducted. Latex gloves are not recommended in classroom because of the potential for latex alleries, but rather nitrile gloves are recommended. Gloves should be inspected for discoloration, punctures or tears. Gloves should be removed carefully, inverted inside out as they are removed and disposed of properly. If hazardous chemicals or biohazardous materials were used and there is the potential for contamination, the gloves should be disposed of in the hazardous waste containers provided. Specialized gloves for hot materials should be worn when handling hot items, or when handling sharp items.

LABORATORY CLOTHING

The clothing worn by a laboratory worker or student can be important to their safety.

Such workers should not wear loose (neckties), skimpy (shorts), or torn clothing and unrestrained longhair.
Loose or torn clothing and unrestrained long hair can easily catch fire, dip into chemicals, or become ensnarled in moving laboratory equipment; skimpy clothing offers little protection to the skin in the event of a chemical splash.

Perforated shoes, sandals, or cloth sneakers should not be worn in laboratories or where mechanical work is being done.

Lab coats are intended to prevent contact via a chemical splash or a spill. The cloth lab coat is, however, primarily a protection for clothing, and may itself present a hazard (combustibility) to the wearer.

Lab coats should only be worn inside the laboratory to avoid the possibility of contamination outside the lab confines.

Rubber Aprons provide better protection from corrosive or irritating liquids in the event of a splash or spill.

Laboratory workers and students should know the appropriate technique for removing protective apparel, especially any that has been contaminated. Such items should be removely promptly and decontaminated or discarded to prevent the possibility of chemical burn or exposure.

Safety showers should be readily accessible for use when a chemical spill contaminates large sections of clothing.

Appendix A-3

SAFETY EQUIPMENT FOR THE LABORATORY

The following was extracted and adapted from Prudent Practice for Handling Hazardous Chemicals in Laboratories, (National Research Council, 1981).

Safety and emergency equipment must be provided by departments responsible for laboratories and be readily available in the laboratories. The protection afforded by this equipment depends on its proper and consistent use. Laboratory workers should realize that safety devices are intended to help protect them from injury and should not avoid using such devices when they are needed.

All laboratories in which chemicals are used should have available fire extinguishers, safety showers, and eyewash fountains, as well as laboratory hoods and laboratory sinks (which can be considered part of the safety equipment of the laboratory); respiratory protection for emergency use should be available nearby, along with fire alarms, emergency telephones, and identified emergency telephone numbers. Persons expected to use emergency respiratory protection or fire extinguishers must be trained in proper use of the equipment.

In addition to these standard items, there may also be a need for other protection. The laboratory supervisor is responsible for recommending and providing supplementary safety equipment as needed. The special precautions needed when dealing with DNA biological experiments and with radioisotopes are not within the scope of this Appendix; such material can be found elsewhere [*Guidelines for Research Involving Recombinant DNA Molecules* 45 Fed. Reg. 25,366-25,370 (1980) and U.S. Nuclear Regulatory Commission *Rules and Regulations*, 10 CFR Chap. 1, check Appendix C and/or L, or contact the campus chemical hygiene officer].

FIRE SAFETY EQUIPMENT

Typical fire safety equipment in the laboratory includes a variety of fire extinguishers and may include fire hoses, blankets, and automatic extinguishing systems.

Fire Extinguishers

All chemical laboratories should be provided with carbon dioxide or dry chemical fire extinguishers (or both). Other types of extinguishers should be available if required by the work being done. The four types of extinguishers most commonly used are classified by the type of fire (see below) for which they are suitable.

1. Water extinguishers are effective against burning paper and trash (Class A fires). These should not be used for extinguishing electrical, liquid, or metal fires.

2. Carbon dioxide extinguishers are effective against burning liquids, such as hydrocarbons or paint, and electrical fires (Classes B and C fires). They are recommended for fires involving delicate instruments and optical systems because they do not damage such equipment. They are less effective against paper and trash or metal fires and should not be used against lithium aluminum hydride fires.

3. Dry powder (or dry chemical) extinguishers, which contain sodium bicarbonate, are effective against burning liquids and electrical fires (Classes B and C fires). They are less effective against paper and trash or metal fires. They are **not** recommended for fires involving delicate instruments or optical systems because of the cleanup problem this creates. These extinguishers are generally used where large quantities of solvent may be present.

4. Met-L-X extinguishers and others that have special granular formulations are effective against burning metal (Class D fires). Included in this category are fires involving magnesium, lithium, sodium, and potassium; alloys of reactive metals; and metal hydrides, metal alkyls, and other organometallics. These extinguishers are less effective against paper and trash, liquid, or electrical fires.

Every extinguisher should carry a label indicating what class or classes of fires it is effective against. There are a number of other more specialized types of extinguishers available for unusual fire hazard situations. Each laboratory worker is responsible for knowing the location, operation, and limitations of the fire extinguishers in the work area. It is the responsibility of The laboratory supervisor is responsible for ensuring that **all laboratory workers are shown the locations of nearby fire extinguishers and are trained in their use.** After use, an extinguisher should be recharged or replaced by designated personnel. Contact facilities management or the campus chemical hygiene officer for more information.

The University of Maine System requires that fire extinguishers are inspected at least annually. A tag should be affixed to each extinguisher indicating that it has been inspected. If there is a fire extinguisher that does not have an inspection tag, is in need of an inspection, or has a pressure indicator indicating the need for recharging, contact facilities management or the campus chemical hygiene officer.

Fire Hoses

Fire hoses are intended for use by trained firefighting personnel against fires too large to be handled by extinguishers but are included as safety equipment in some structures. Water has a cooling action and is effective against fires involving paper, wood, rags, trash, and such (Class A fires). Water should not be used directly on fires that involve live electrical equipment (Class C fires) or chemicals such as alkali metals, metal hydrides, and metal alkyls that react vigorously with it (Class D fires).

Streams of water should not be used against fires that involve oils or other water-insoluble flammable liquids (Class B fires). This form of water will not readily extinguish such fires, and it will usually spread or float the fire to adjacent areas. These possibilities are minimized by the use of a water fog or mist.

Water fogs are used extensively by the petroleum industry because of their fire-controlling and extinguishing properties. A fog can be used safely and effectively against fires that involve oil products, as well as those involving wood, rags, rubbish, and such.

Because of the potential hazards in using water around chemicals (and the problem of controlling a hose delivering water at significant pressures), **laboratory workers should refrain from using fire hoses except in extreme emergencies. Such use should be reserved for trained firefighting personnel.**

Fire Blankets

Many laboratories still have fire blankets available. A fire blanket is **used primarily as a first aid measure for the prevention of shock rather than against smoldering or burning clothing.** Using a fire blanket to extinguish clothing fires should be a last resort measure: such blankets tend to hold heat in and increase the severity of burns. Clothing fires should be extinguished by immediately dropping to the floor and rolling or, if a safety shower (see below) is immediately available, using it.

Automatic Fire-Extinguishing Systems

In areas where fire potential (for example, solvent storage areas) and the risk of injury or damage are high, automatic fire-extinguishing systems are often used. These may be of the water-sprinkler, carbon dioxide, dry chemical, or halogenated hydrocarbon types. Whenever it has been determined that the risk justifies an automatic fire-extinguishing system, the laboratory workers should be informed of its presence and advised of any safety precautions required for its action (*e.g*., evacuation before a carbon dioxide total-flood system is actuated).

RESPIRATORY PROTECTIVE EQUIPMENT

The primary method for the protection of laboratory personnel from airborne contaminants should be to minimize the amount of such materials entering the laboratory air or using engineering controls such as localized ventilation (for example, laboratory ventilation hoods). When effective engineering controls are not possible, suitable respiratory protection should be provided. The laboratory supervisor is responsible for determining when such protection is needed and ensuring that it is used.

Under OSHA regulations, only equipment listed and approved by the Mine Safety and Health Administration (MSHA) and the National Institute for Occupation Safety and Health (NIOSH) may be used for respiratory protection. Also under the regulations, each site on which respiratory protective equipment is used must implement a respiratory protection program in compliance with the standard (29 CFR 1910.134) (see also ANSI Z88.2). No laboratory supervisor is to issue respiratory protective equipment without a written respiratory protection program outlining training and fitting requirements.

Types of Respirators

Several types of nonemergency respirators are available for protection in atmospheres that are not immediately dangerous to life of health but could be detrimental after prolonged or repeated exposure. Other types of respirators are available for emergency or rescue work in atmospheres from which the wearer cannot escape without respiratory protection. In either case, additional protection may be required if the airborne contaminant is of a typed that could be absorbed through or irritate the skin. For example, the possibility of eye or skin irritation may require the use of a full-body suit and a full-face mask rather than a half-face mask.

The choice of the appropriate respirator to use in a given situation will depend on the type of contaminant and its estimated or measured concentration, known exposure limits, and warning and hazardous properties (*e.g.*, eye irritation or skin absorption). The degree of protection afforded by the respirator varies with the type. The following are some common types of respirators:

1.*Chemical cartridge respirators* -

a) Can be used only for protection against particular individual (or classes of) vapors or gases as specified by the respirator manufacturer and cannot be used at concentrations of contaminant above that specified on the cartridge.

b) Cannot be used if the oxygen content of the air is less than 19.5%, in atmospheres immediately dangerous to life, of for rescue or emergency work.

c) Function by the entrapment of vapors and gases in a cartridge or canister that contains a sorbent material. Activated charcoal is probably the most common adsorbent.

d) Have the potential for significant breakthrough of the hazardous substance to occur at a fraction of the canister capacity. Knowledge of the potential workplace exposure and length of time the respirator will be worn is important in determining breakthrough potential. Replace the cartridge after each use to ensure the maximum available exposure time for each new use.

e) Difficulty in breathing or the detection of odors indicates plugged or exhausted filters or cartridges or concentrations of contaminants higher than the absorbing capability of the cartridge; such items should be replaced promptly (if necessary, by a more effective type of respirator).

f) Must fit snugly to the face to be effective. Conditions that prevent facepiece-to-face seal (for example, temple pieces of glasses or facial hair) will permit contaminated air to bypass the filter, possibly creating a dangerous situation for the user. Tests for the proper fit of the respirator on the user should be conducted prior to its selection and verified before he or she enters the area of contamination.

g) Organic vapor cartridge cannot be used for vapors that have poor warning properties or those that will generate high heats of reaction with the sorbent materials in the cartridge.

2. *Dust, fume, and mist respirators*--

a) Can be used only for protection against particular individual (or classes of) dusts, fumes, and mists as specified by the manufacturer.

b) Usually trap the particles in a filter composed of fibers. Respirators of this type are generally disposable. Some examples are surgical masks and 3M toxic-dust masks, which can be used to filter out animal dander and nontoxic and nuisance dusts.

c) Some are NIOSH approved for more specific purposes such as protection against simple or benign dust and fibrogenic dusts and asbestos.

d) Are not 100% efficient in removing particles. The useful life of the filter is dependent on the concentration of contaminant encountered.

e) Afford no protection against gases or vapors and should not be used when handling chemicals. They provide little if any protection and may give the user a false sense of security.

f) Are also subject to the limitations of fit described above.

3. *Supplied-air respirators*--

a) Supply fresh air to the facepiece of the respirator at a pressure high enough to cause a slight buildup relative to atmospheric. As a result, the supplied air flows outward from the mask and contaminated air from the wok environment cannot readily enter the mask. This characteristic renders face-to-facepiece fit less important than with other types of respirators. Fit testing is, however, required before selection and use.

b) Are effective protection against a wide range of air contaminants (gases, vapors, and particulates) and can be used where oxygen-deficient atmospheres are present.

c) Are free from the maintenance problems associated with charcoal, particulate, and chemical scrubbing filters.

d) Can be used where concentrations of air contaminants could be immediately dangerous to life or from which the wearer could not escape unharmed without the air of the respirator provided:

(1) the protection factor of the respirator is not exceeded

(2) the provisions of 29 CFR 1910.134 are not violated.

e) must have an air supply that is kept free of contaminants (*e.g*,. by use of oil filters and CO absorbers), and some consideration should be given to its air quality and relative humidity. Most laboratory air is not suitable for use with these units.

f) Usually require the user to drag long lengths of hose connected to the air supply. Thus, the range of their use is limited to the maximum length of hose specified by the manufacturer. Some supplied-air units are used in combination with self-contained apparatus.

4. *Self-contained breathing apparatus*--

a) The only type of respiratory protective equipment suitable for emergency or rescue work.

b) Consists of a full-face mask connected to a cylinder of compressed air and has no limitations with regard to its use in areas of toxic contaminants or oxygen deficiency.

c) Cannot be used for extended periods without recharging or replacing the cylinders because the air supply is limited to the capacity of the cylinder (5- to 30-min use time).

d) For safety reasons, the "pressure/demand" type, which always has a positive pressure within the mask is much preferred to the "demand" type.

e) Are bulky and heavy, and additional protective apparel may still be required depending on the nature of the hazard.

f) All institutions or organizations that have laboratories in which chemicals are used should have protective equipment of this type available for emergencies and provide training in its use to selected personnel.

Procedures and Training

Each area within the University of Maine System where respirators are used should have written information available that shows the limitations, fitting methods, and inspection and cleaning procedures for each type of respirator available. Personnel who may have occasion to use respirators in their work must be thoroughly trained in the fit testing, use limitations, and care of such equipment. This information should be found in the campus Respiratory Protection Program.

The following elements should appear in the campus Respiratory Protection Program:

Training should be provided to the users of respirators that includes demonstration and practice in wearing, adjusting, and properly fitting the equipment. OSHA regulations require that a worker be examined by a physician before beginning work in an area where a respirator must be worn [29 CFR 1910.134(b)(10)].

Respirators for routine use should be inspected before each use by the user and periodically by the laboratory supervisor. Self-contained breathing apparatus should be inspected once a month and cleaned after each use. Defective units should not be used but should be repaired by a qualified person or replaced promptly.

No laboratory supervisor is to issue nor is a laboratory worker to use respiratory protective equipment without a written respiratory protection program outlining training, fitting, and medical requirements as outlined in 29 CFR 1910.134.

SAFETY SHOWERS AND EYEWASH FOUNTAINS

Safety Showers

Chemicals should only be handled where safety showers are provided for immediate first aid treatment of chemical splashes and for extinguishing clothing fires. Conversely, safety showers should be provided in areas where chemicals are handled by the department having jurisdiction over the area. Every laboratory worker should learn the locations of and how to use the safety showers in the work area so that he or she can find them with eyes closed, if necessary. Safety showers should be tested routinely by laboratory personnel to ensure that the valve is operable and to remove any debris in the system.

The shower should be capable of drenching the subject immediately and should be large enough to accommodate more than one person if necessary. It should have a quick-opening valve requiring manual closing; a downward-pull delta bar is satisfactory if long enough but chain pulls are not advisable in new installations because of the potential for persons to be hit by them and the difficulty of grasping them in an emergency.

Eyewash Fountains

Eyewash fountains are required if substances in use present an eye hazard or in research or instructional laboratories where unknown hazards may be encountered. An eyewash fountain should provide a soft stream of spray of aerated water for an extended period (15 min). These fountains should be located close to the safety showers so that, if necessary, the eyes can be washed while the body is showered. Portable eyewash bottles are an unacceptable substitute for eyewash fountains. These bottles do not provide for the 15-minutes needed to properly flush the eyes as described in standard first aid procedures. Eyewash bottles may even become a biological hazard if the water is not changed regularly or sterilized.

The University of Maine System has adopted American National Standards Institute (ANSI) standard Z358.1-1981 "Emergency Eyewash and Shower Equipment." Some of the requirements in this standard include the following:

SHOWERS
Shower Head Height - 82 to 96 inches
Spray Pattern -20 inch minimum diameter at 60 inches from standing level.
Water Delivery-30 gallons per minute (GPM) at 30 pounds per square inch.
Control Valve -Remains open when activated. Off to on in 1 second or less.
Location - - -Must be accessible, within 100 feet of work area, and require no more than 10 seconds to reach.
Identification-Well lit, highly visible sign.
Water - - - - -Available for a minimum of 15 minutes.

EYEWASH STATIONS
Wash Delivery - 0.4 gallons per minute for 15 minutes at 30 pounds per square inch.
Nozzle Height -45 inches from floor. Nozzles must be protected from airborne contaminants.
Control Valve - Remains open when activated. Off to on in 1 second or less.
Location - - -Must be within 100 feet of work area and require no more than 10 seconds to reach.
Identification-Well lit, highly visible sign.

EYE/FACE WASH EQUIPMENT
Water Delivery-3 gallons per minute for 15 minutes at a minimum of 30 pounds per square inch of pressure.
Nozzle Height -45 inches from floor.
Location - - -Must be within 100 feet of work area and require no more than 10 seconds to reach.

HAND HELD DRENCH HOSE
Water Delivery-3 gallons per minute at 30 pounds per square inch of pressure.

MAINTENANCE AND TRAINING
All eyewash or shower equipment should be activated periodically (weekly) to verify operation. Such equipment should be formally tested at least annually by maintenance or safety personnel.

All persons using or exposed to corrosive or hazardous materials need to be trained in the use of such equipment.

The ANSI Z358.1-1982 standard should be reviewed for further requirements. The important point to remember is that the first 10-15 seconds of any accidental chemical or corrosive material contact is a very critical period. Thorough flushing should start immediately to help reduce further chance of severe injury.

OTHER SAFETY EQUIPMENT

Safety Shields

Safety shields should be used for protection against possible explosions or splash hazards. Laboratory equipment should be shielded on all sides so that there is no line-of-sight exposure of personnel.

Provided its opening is covered by closed doors, the conventional laboratory exhaust hood is a readily available built-in shield. However, a portable shield should also be used when manipulations are performed, particularly with hoods that have vertical-rising doors rather than horizontal-siding sashes.

Portable shields can be used to protect against hazards of limited severity, *e.g.*, small splashes, heat, and fires. A portable shield, however, provides no protection at the sides or back of the equipment and many such shields are not sufficiently weighted and may topple toward the worker when there is a blast (perhaps hitting him or her and also permitting exposure to flying objects). A fixed shield that completely surrounds the experimental apparatus can afford protection against minor blast damage.

Methyl methacrylate, polycarbonate, polyvinyl chloride, and laminated safety plate glass are all satisfactory transparent shielding materials. Where combustion is possible, the shielding material should be nonflammable or slow burning; if it can withstand the working blast pressure, laminated safety plate glass may be the best material for such circumstances. When cost, transparency, high tensile strength, resistance to bending loads, impact strength, shatter resistance, and burning rate are considered, methyl methacrylate offers an excellent overall combination of shielding characteristics. Polycarbonate is much stronger and self-extinguishing after ignition but is readily attacked by organic solvents.

Stretchers

Although stretchers are often provided in areas where chemicals are handled, untrained personnel should use them only in life-threatening situations. The best approach is generally not to move a seriously injured person until qualified medical help arrives.

Storage And Inspection Of Emergency Equipment

Establishment of a central location for storage of emergency equipment may be useful in the laboratory. Such a location may contain the following:

1. self-contained breathing apparatus (for emergency entry or rescue)
2. safety belt with rope (to maintain contact with rescuers entering a laboratory under emergency conditions)
3. blankets for covering injured persons
4. stretchers
5. first aid equipment (for unusual situations such as exposure to cyanide, where immediate first aid is required).

Safety equipment should be inspected regularly (*e.g.*, every 3 to 6 months) to ensure that it will function properly when needed. The laboratory supervisor or safety coordinator is responsible for establishing a routine inspection system and to verify that inspection records are kept.

1. Fire extinguishers should be inspected for broken seals, damage, and low gage pressure (depending on type of extinguisher).

2. Proper mounting of fire extinguishers and its accessibility should also be checked. Some types of extinguishers must be weighed annually and periodic hydrostatic testing should also be conducted.

3. Self-contained breathing apparatus should be checked at least once a month (and after each use) to determine whether proper air pressure is being maintained. The examiner should look for signs of deterioration or wear or wear of rubber parts, harness, and hardware and make certain that apparatus is clean and free of visible contamination.

3. Safety showers and eyewash fountains should be examined visually and their mechanical function should be tested.

Appendix A-4

ELECTRICAL EQUIPMENT IN THE LABORATORY

{The following was extracted and adapted from *Prudent Practices For Handling Hazardous Chemicals in Laboratories* *(National Research Council, 1981)*

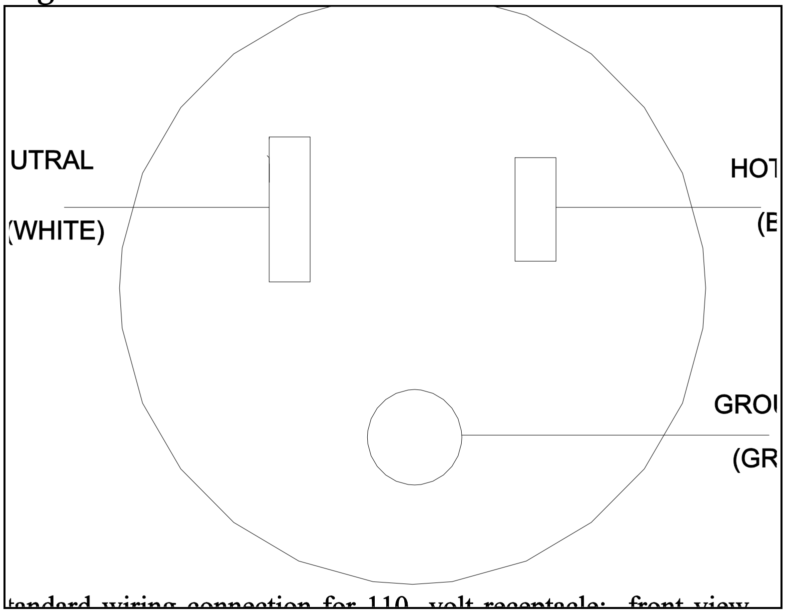
During the past 35 years, the use of electrically powered apparatus in laboratories has increased more rapidly than that of any other category of equipment. Such equipment is now used routinely for operations requiring heating, cooling, agitation or mixing, and pumping, as well as for a variety of instruments used in making physical measurements. In fact, electrical apparatus is now so commonly available that it, rather than burners or other devices that have open flames, should be the only type of heat source present in operations involving the use of flammable materials. However, although the introduction of electrically powered equipment has resulted in a major improvement in laboratory safety, the use of this equipment does pose a new set of possible hazards for the unwary.

GENERAL PRINCIPLES

Laboratory workers should know the procedures for removing a person from contact with a live electrical conductor and the emergency first aid procedures to use for a person who has received a serious electrical shock (see Appendix X).

All 110-V outlet receptacles in laboratories should be of the standard design that accepts a three-prong plug and provides a ground connection. The use of an old-style two-prong receptacle and an adapter that takes a three-prong plug is a less satisfactory alternative; however, no attempt should be made to bypass the ground. Old-style receptacle should be replaced as soon as feasible, and additional ground wire should be added if necessary so that each receptacle is wired as shown in Figure 1. If the use of an extension cord becomes necessary, standard three-conductor extension cords that provide an independent ground connection should be used.

Figure 1



tandard wiring connection for 110 volt receptacle: front view

It is also possible to fit a receptacle with a ground-fault circuit breaker that will disconnect the current if continuity is lost in the system. Such ground-fault protection devices are frequently recommended for outdoor receptacles by local electrical codes and would be useful for selected laboratory receptacles where maintenance of a good ground connection is essential for safe operation.

Receptacles that provide electric power for operations in hoods should be located outside of the hood. This location prevents the production of electrical sparks inside the hood when a device is plugged in and also allows a laboratory worker to disconnect electrical devices from outside the hood. However, cords should not be allowed to dangle outside the hood in such a way that a worker could accidentally pull them.

Laboratory equipment that is to be plugged into a 110-V (or higher) receptacle should be fitted with a standard three-conductor line cord that provides an independent ground connection to the chassis of the apparatus (although in some instances "double-insulated" equipment that has a two-conductor line cord may be adequate). All frayed or damaged line cords should be replaced before further use of the equipment is permitted; annual inspection of all electrical cords is good practice. It is also desirable that equipment that will be plugged into an electrical receptacle be fitted with a fuse or other overload-protection device that will disconnect the electrical circuit in the event the apparatus fails or is overloaded. This overload protection is particularly useful for apparatus likely to be left on and unattended for long time periods [such as variable autotransformers (Variacs® and Powerstats®), vacuum pumps, drying ovens, stirring motors, and electronic instruments]. New or existing equipment that does not contain this overload protection can be modified to provide such protection.

Motor-driven electrical equipment used in a laboratory where volatile flammable materials may be present should be equipped with a non-sparking induction motor rather than with a series-wound motor that uses carbon brushes. This applies to the motors used in vacuum pumps, mechanical shakers, and (especially) stirring motors, magnetic stirrers, and rotary evaporators. The speed of an induction motor operating under a load should not be controlled by using a variable autotransformer. Such circumstances will cause the motor to overheat and might start a fire. There is no way to modify an apparatus that has a series-wound motor so that it will be spark-free. For this reason, many kitchen appliances (mixers, blenders, and such) should not be used in laboratories where flammable materials may be present. Finally, it should be remembered that, when other items of equipment (especially vacuum cleaners and portable electric drills) having series-wound motors are brought into a laboratory for special purposes, special precautions should be taken to ensure that no flammable vapors are present before such equipment is used (see Appendix A-6).

Whenever possible, electrical equipment should be located so as to minimize the possibility that water or chemicals could accidentally be spilled on it. If water or any chemical should accidentally be spilled on electrical equipment, the equipment should be unplugged immediately and not used again until it has been cleaned and inspected (preferably by a qualified technician). Water can also enter electrical equipment from condensation on equipment placed in a cold room or a large refrigerator. Cold rooms pose a particular hazard in this respect. The atmosphere in such rooms is frequently at a high relative humidity and the potential for water condensate is significant. If electrical equipment must be placed in such areas, the condensation problem can be lessened (but not eliminated) by mounting the equipment on a wall or vertical panel. The potential for electrical shock in these rooms can be minimized by careful electrical grounding of the equipment and the use of a suitable flooring material.

All laboratories should have access to a qualified technician who can make routine repairs to existing equipment and modifications to new or existing equipment so that it will meet reasonable standards for electrical safety [contact your Facilities Management or Physical Plant Office].

With the exception of certain instrument adjustments, line cords of electrical equipment should always be unplugged before any adjustments, modifications, or repairs are undertaken. When it is necessary to handle a piece of electrical equipment that is plugged in, laboratory workers should first be certain that their hands are dry.

VACUUM PUMPS

Distillations or concentration operations that involve significant quantities of volatile substances should normally be performed by using a water aspirator or a steam aspirator, rather than by using a mechanical vacuum pump. However, the distillation of less-volatile substances, removal of final traces of solvents, and some other operations require pressures lower than those that can be obtained by using a water aspirator and are normally performed by using a mechanical vacuum pump should be fitted with a cold trap to collect volatile substances from the system and minimize the amount that enters the vacuum pump and dissolves in the pump oil; the use of liquid nitrogen or liquid air in such traps, however, can lead to a flammability hazard (see Appendix A-6).

The output of each pump should be vented to an air exhaust system. This procedure is essential when the pump is being used to evacuate a system containing a volatile toxic or corrosive substance (failure to observe this precaution would result in pumping the substance into the laboratory atmosphere); it may also be necessary to scrub or absorb vapors. Even with these precautions, however, volatile toxic or corrosive substances may accumulate in the pump oil and, thus, be discharged into the laboratory atmosphere during future pump use. This hazard should be avoided by draining and replacing the pump oil when it becomes contaminated. The contaminated pump oil should be disposed of by following standard procedures for the safe disposal of toxic or corrosive substances.

DRYING OVENS

Electrically heated ovens are commonly used in the laboratory to remove water or other solvents from chemical samples and dry laboratory glassware before its use. With the exception of vacuum drying ovens, these ovens rarely have any provision for preventing the discharge of the substances volatilized in them into the laboratory atmosphere. Thus, it should be assumed that these substances will escape into the laboratory atmosphere and could also be present in concentrations sufficient to form explosive mixtures with the air inside the oven.

Ovens should not be used to dry any chemical sample that has even moderate volatility and 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. Thus, most organic compounds should not be dried in a conventional laboratory oven.

Glassware that has been rinsed with an organic solvent should not be dried in an oven. If such rinsing is necessary, the item should be rinsed again with distilled water before being placed in the oven.

Because of the possible formation of explosive mixtures by volatile substances and the air inside an oven, laboratory ovens should be constructed so that their heating elements (which may become red hot) and their temperature controls (which may produce sparks) are physically separated from their interior atmospheres. Many small household ovens and similar heating devices do not meet these requirements and, consequently, should not be used in laboratories. Existing ovens that do not meet these requirements should either be modified or have a sign attached to the oven door to warn workers that flammable materials should not be placed in that oven. Some safety groups suggest that every laboratory oven should be modified by placing a blow-out panel in its rear wall so that any explosion within the oven will not blow the oven door and the oven contents into the laboratory. NFPA standards call for blow-out vents on ovens handling flammable substances.

Thermometers containing mercury should not be mounted through holes in the tops of ovens so that the bulb of mercury hangs into the oven. Bimetallic strip thermometers are the preferred alternative for monitoring oven temperatures. Should a mercury thermometer be broken in an oven of any type, the oven should be turned off and all mercury should be removed from the cold oven.

REFRIGERATORS

The potential hazards posed by laboratory refrigerators are in many ways similar to those of laboratory drying ovens. Because there is almost never a satisfactory arrangement for continuously venting the interior atmosphere of a refrigerator, any vapors escaping from vessels placed in one will accumulate. Thus, the atmosphere in a refrigerator could contain an explosive mixture of air and the vapor of a flammable substance or a dangerously high concentration of the vapor of a toxic substance or both. (The problem of toxicity is aggravated by the practice of laboratory workers who place their faces inside the refrigerator while searching for a particular sample, thus ensuring the inhalation of some of the atmosphere from the refrigerator interior.) As noted in Appendix A-1, laboratory refrigerators should never be used for the storage of food or beverages.

There should be no potential sources of electrical sparks on the inside of a laboratory refrigerator. In general, it is preferable when purchasing a refrigerator for a laboratory to select a "flammable storage" one that has been so designed by the manufacturer. If this is not possible, all new or existing refrigerators should be modified as needed by

(a) removing any interior light activated by a switch mounted on the door frame,

(b) moving the contacts of the thermostat controlling the temperature to a position outside the refrigerated compartment

(c) moving the contacts for any thermostat present to control fans within the refrigerated compartment to the outside of the refrigerated compartment.

Although a prominent sign warning against the storage of flammable substances could be permanently attached to the door of an unmodified refrigerator, this alternative is less desirable than the modification of the equipment by removal of all spark sources from the refrigerated compartment. "Frost-free" refrigerators are not advisable for laboratory use because of the many problems associated with attempts to modify them. Many of these refrigerators have a drain tube or hole that carries water (and any flammable material present) to an area adjacent to the compressor and, thus, present a spark hazard; the electric heaters used to defrost the freezing coils are also a potential spark hazard.

Laboratory refrigerators should be placed against fire-resistant walls, have heavy-duty cords, and preferably should be protected by their own circuit breaker.

Uncapped containers of chemicals should never be placed in a refrigerator. Containers of chemicals should be capped so as to achieve a seal that is both vapor tight and unlikely to permit a spill if the container is tipped over. Caps constructed from aluminum foil, corks, corks wrapped with aluminum foil, or glass stoppers often do not meet all of these criteria: the use of such methods for capping containers should be discouraged. The most satisfactory temporary seals are normally achieved by using containers that have screw-caps lined with either a conical polyethylene insert or a Teflon insert. The best containers for samples that are to be stored for longer periods of time are sealed, nitrogen-filled glass ampoules.

The placement of potentially explosive or highly toxic substances in a laboratory refrigerator is strongly discouraged. If this precaution must be violated, then a clear, prominent warning sign should be placed on the outside of the refrigerator door. The length of storage of such material in the refrigerator should be kept to a minimum.

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 production of electrical sparks within the hood. Furthermore, it is important that, in the event of an emergency situation, a laboratory worker be able to turn such devices on or off from outside the hood. Finally, heating baths associated with these devices (e.g., baths for rotary evaporators) should also be spark-free and capable of control from outside the hood.

Only spark-free induction motors should be used to run stirring and mixing devices; any motor that may produce sparks during its start-up or running cycle should not be used. Fortunately, the motors in most of the currently marketed stirring and mixing devices meet this criterion. However, the on-off switches and rheostat-type speed controls of many of them do not meet this criterion because the switch or rheostat has exposed contacts that can produce an electrical spark any time a change is made in the controls. This problem is particularly true of many of the magnetic stirrers and rotary evaporators currently being sold. An effective solution is the modification of the stirring or mixing device by removing any switches located on the device and inserting a switch in the line cord near the plug end. As the electrical receptacle for the plug should be outside the hood, this modification will ensure that the switch will also be outside of the hood. Recall that 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 continual attention (e.g., reaction mixtures that are stirred overnight), the consequences of stirrer failure, electrical overload, or blockage of the motion of the stirring impeller should be considered. It is good practice to attach a stirring impeller to the shaft of the stirring motor by using lightweight rubber tubing. Then, if the motion of the impeller becomes blocked (e.g., by formation of a copious precipitate), the rubber simply twists until it breaks rather than either the motor stalling or the glass apparatus into which the stirring impeller extends breaking. It is also very desirable (but unfortunately not very common) that stirring motors that are to be left unattended be fitted with a suitable fuse or thermal-protection device.

HEATING DEVICES

Perhaps the most common electrical equipment found in a laboratory are the devices used to supply the heat needed to effect a reaction or a separation. (The use of steam-heated devices rather than electrically heated devices is generally preferred whenever temperatures of 100°C or less are required; these devices do not present shock or spark hazards and can be left unattended with assurance that their temperature will never exceed 100°C.) These electrically heated devices include hot plates, heating mantles and tapes, oil baths, air baths, hot-tube furnaces, and hot-air guns. Although they are inherently much safer than burners as laboratory heat sources, such devices can still pose both electrical and fire hazards if used improperly.

1. The actual heating element in any laboratory heating device should be enclosed in a glass, ceramic, or insulated metal case such that it is not possible for the laboratory worker (or some metallic conductor) to accidentally touch the wire carrying the electric current. This practice minimizes the hazards of electrical shock and of accidentally producing an electrical spark near a flammable liquid or vapor. This type of construction also diminishes the possibility that a flammable liquid or vapor will come in contact with the hot wire (whose temperature is frequently higher than the ignition temperature of any common solvents). If any heating device becomes so worn or damaged that its heating element is exposed, the device should either be discarded or repaired to correct the damage before it is again used in the laboratory. Note that many household appliances (e.g., hot plates and space heaters) do not meet this criterion and, consequently, are not advisable for use in the laboratory.

2. The temperature of many laboratory heating devices (e.g., heating mantles, air baths, and oil baths) is controlled by use of a variable autotransformer that supplies some fraction of the total line voltage (typically 110 V) to the heating element of the device. Some older models have wiring configurations which may pose a risk to the user. Whenever a variable autotransformer whose wiring is not definitely known to be acceptable is used, it is best to assume that either of the output lines could be at a potential of 110 V and capable of delivering a lethal electric shock. The cases of all variable autotransformers have numerous openings to allow for ventilation and some sparking may occur whenever the voltage adjustment knob is turned; laboratory workers should be careful to locate these devices where water and other chemicals cannot be spilled on them (shock hazard) and where their movable contacts will not be exposed to flammable liquids or vapors (fire hazard). Specifically, variable autotransformers should be mounted on walls or vertical panels and outside of hoods; they should not just be placed on laboratory bench tops, especially those inside of hoods.

3. Because the electrical input lines (even lines from variable transformers) to almost all laboratory heating devices may well be at a potential of 110 V with respect to any electrical ground, these lines should always be considered both as potential shock hazards and as potential spark hazards. Thus, any connection from these lines to a heating device should be both mechanically and electrically secure and completely covered with some insulating material. Alligator clips should not be used to connect a line cord from a variable autotransformer to a heating device (especially an oil bath or an air bath) because such connections pose a shock hazard and also may slip off, creating an electrical spark and, perhaps, contacting other metal parts to create a new hazard. All connections should be made by using either insulated binding posts or, preferably, a plug and receptacle combination.

4. Whenever an electrical heating device is to be left unattended for a significant period of time (e.g., overnight), it is advisable that it be equipped with a temperature-sensing device that will turn off the electric power if the temperature of the heating device exceeds some preset limit. Similar control devices are available that will turn off the electric power if the flow of cooling water through a condenser is unexpectedly stopped. Such fail-safe devices, which can either be purchased or constructed by a qualified technician, prevent more serious problems (fires or explosions) that may arise if the temperature of an unattended reaction should increase significantly either because of a change in line voltage or because of accidental loss of reaction solvent. These devices are also valuable accessories for use with stills employed to purify reaction solvents because such stills are often left unattended for significant periods of time.

LABORATORY HOT PLATES

Laboratory hot plates are normally used when solutions are to be heated to 100°C or above and the inherently safer steam baths cannot be used as the source of heat. As noted above, only hot plates that have completely enclosed heating elements should be used in laboratories. Although almost all laboratory hot plates now being sold meet this criterion, many older ones pose an electrical-spark hazard arising from the on-off switch located on the hot plate, the bimetallic thermostat used to regulate the temperature of the hot plate, or both. Normally, these two spark sources are both located in the lower part of the hot plate in a region where any heavier-than-air (and possibly flammable) vapor escaping from a boiling liquid on the hot plate would tend to accumulate. In principle, these spark hazards could be alleviated by enclosing all mechanical contacts in a sealed container or by the use of solid-state circuitry for switching and temperature control but, in practice, such modifications would be difficult to incorporate in many of the hot plates now used in laboratories. Laboratory workers should be warned of the spark hazard associated with many existing hot plates (perhaps by attaching a warning label), and any new hot plates purchased should be constructed in a way that avoids electrical spark hazards. In addition to the spark hazard, old and corroded bimetallic thermostats in these devices can eventually fuse shut, thus delivering full current to the hot plate. This hazard can be avoided by wiring a fusible coupling into the line inside the hot plate so that if the device does overheat, the coupling will melt and interrupt the current.

HEATING MANTLES

Heating mantles are commonly used for heating round-bottomed flasks, reaction kettles, and related reaction vessels. These mantles are constructed by enclosing the heating element in a series of layers of fiberglass cloth. As long as the fiberglass coating is not worn or broken or no water or other chemicals are spilled into the mantle, these mantles pose no shock hazard to the worker. They are normally fitted with a male plug that fits into a female receptacle on an output line from a variable autotransformer to provide a connection that is mechanically and electrically secure.

Heating mantles are always intended to be used with a variable autotransformer to control the input voltage and should never be plugged directly into a 110-V line. Laboratory workers should be careful not to exceed the input voltage recommended by the manufacturer of the mantle because higher voltages will cause it to overheat, melting the fiberglass insulation and exposing the bare (and often red-hot) heating element. Note that the maximum recommended input voltage for a mantle that is being used with a dry flask is 10-20 V lower than that for a mantle that is being used with a flask containing liquid. Some heating mantles are constructed by encasing the fiberglass mantle in an outer metal case that provides physical protection against damage to the fiberglass. If such metal-enclosed mantles are used, it is good practice to ground the outer metal case either by use of a three-conductor cord (containing a ground wire) from the variable autotransformer or by attaching one end of a heavy ground such as a cold-water pipe. This practice provides the laboratory worker with protection against an electric shock if the heating element inside the mantle should be shorted against the metal case.

OIL BATHS

Electrically heated oil baths are often used as heating devices for small or irregularly shaped vessels or when a stable heat source that can be maintained at a constant temperature is desired. For temperatures below 200°C, a saturated paraffin oil is often used; a silicone oil (which is more expensive) should be used for temperatures up to 300°C. An oil bath should always be monitored by using a thermometer or other thermal-sensing device to ensure that its temperature does not exceed the flash point of the oil being used. For the same reason, oil baths left unattended should be fitted with thermal-sensing devices that will turn off the electric power if the bath overheats. Bare wires should not be used as resistance devices to heat oil baths. Rather, these baths should be heated with a metal pan fitted with an enclosed heating element or with a heating element such as a Calrod®, or its equivalent). The input connection for this heating element should be a male plug that will fit a female receptacle from a variable autotransformer output line.

Heated oil should be contained in either a metal pan or a heavy-walled porcelain dish; a glass dish or beaker can break and spill hot oil if accidentally struck with a hard object. The oil bath should be carefully mounted on a stable horizontal support such as a laboratory jack that can be easily raised or lowered without danger of the bath tipping over. A bath should never be supported on an iron ring because of the greater likelihood of accidentally tipping it over. Finally, a laboratory worker using an oil bath heated above 100°C should be careful to guard against the possibility that water (or some other volatile substance) could fall into the hot bath. Such an accident can splatter hot oil over a wide area.

AIR BATHS

Electrically heated air baths are frequently used as a substitute for heating mantles when heating small or irregularly shaped vessels. Because of their inherently low heat capacity, such baths normally must be heated considerably above (100°C or more) the desired temperature of the vessel being heated. These baths should be constructed so that the heating element is completely enclosed and the connection to the air bath from the variable transformer is both mechanically and electrically secure. These baths can be constructed from metal, ceramic, or (less desirably) glass vessels. If glass vessels are used, they should be thoroughly wrapped with a heat-resistant tape so that, if the vessel is accidentally broken, the glass will be retained and the bare heating element will not be exposed.

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, necessarily, cannot be enclosed. Also, the on-off switches and fan motors are not usually spark free. For these reasons, heat guns almost always pose a serious spark hazard. They should never be used near open containers of flammable liquids, in environments where appreciable concentrations of flammable vapors may be present, or in hoods that are being used to remove flammable vapors. Household hair dryers should be used as substitutes for laboratory heat guns only if they have three-conductor or double-insulated line cords.

Appendix A-5

WORKING WITH ACUTELY TOXIC, CHRONICALLY TOXIC, OR CORROSIVE SUBSTANCES

The following was extracted and adapted from Prudent Practice for Handling Hazardous Chemicals in Laboratories, (National Research Council, 1981).

Many of the chemicals encountered in the laboratory are known to be toxic or corrosive or both. New and untested substances that may be hazardous are also frequently encountered. Thus, it is essential that all laboratory workers understand the types of toxicity, know the routes of exposure, and recognize the major classes of toxic and corrosive chemicals. These items are described below.

When considering possible toxicity hazards while planning an experiment, it is important to recognize that the combination of the toxic effects of two substances may be significantly greater than the toxic effect of either substance alone. Always assume that mixtures of different substances (ie. chemical reaction mixtures) will be more toxic than the most toxic ingredient contained in the mixture. Furthermore, chemical reactions involving two or more substances may form reaction products that are significantly more toxic than the starting reactants. This possibility of generating toxic reaction products may not be anticipated in cases where the reactants are mixed unintentionally.

Exposure to hazardous chemicals can be prevented or minimized by following procedures detailed in Appendix A-1.

ROUTES OF EXPOSURE

Exposure to chemicals or hazardous substances may occur by the following routes:

A. inhalation
B. ingestion
C. absorption (skin or eyes)
D. injection

A.INHALATION

Inhalation of toxic vapors, mists, gases, or dusts can produce poisoning by absorption through the mucous membrane of the mouth, throat, and lungs and can seriously damage these tissues through local action. Inhaled gases or vapors may pass rapidly into the capillaries of the lungs and be carried into the circulatory system. The rate of absorption will vary with the concentration of the toxic substance, its solubility in tissue fluids, the depth of respiration, and the amount of blood circulation, which means that it will be much higher when the person is active than when at rest.

The degree of injury resulting from exposure depends on the toxicity of the material, its solubility in tissue fluids, concentration, and duration of exposure. Chemical activity and the time of response after exposure are not necessarily a measure of the degree of toxicity. Several chemicals (eg. mercury and its derivatives) and some of the common solvents (benzene) are cumulative poisons that can produce body damage through exposure to small concentrations over a long period of time.

The American Conference of Governmental Industrial Hygienists (ACGIH) produces annual lists of Threshold Limit Values (TLVs®) and Short Term Exposure Limits (STELs) for common chemicals used in laboratories. These published values are guides, **not** legal standards, and are defined as follows:

TLVs® Refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. They are based on the best available information from industrial experience, from experimental human and animal studies, and, when possible, a combination of the three. They are intended for the use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and for no other use.

There are three types of TLVs®:

TLV-TWA Threshold Limit Value - Time Weighted Average is the time-weighted average concentration of a substance for a normal 8-hour workday and a 40-hour work week, to which all workers may be repeatedly exposed, day after day, without adverse effect.

TLV-STEL Threshold Limit Value - Short Term Exposure Limit is the concentration to which workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals. A STEL is defined as a 15-minute TWA exposure which should not be exceeded at any time during the work day.

TLV-C Threshold Limit Value - Ceiling Limit is the concentration that should not be exceeded during any part of the working exposure.

For more information, please refer to the most recently published listing of ACGIH's TLVs® and their definitions. TLVs® provide a useful estimate of how much ventilation may be needed in laboratories where occupants tend to spend most of their working time. However, because of many factors influencing toxicity, each situation should be evaluated individually and the TLVs® used as guidelines rather than fine lines between safe and dangerous concentrations.

The Occupational Safety and Health Administration (OSHA) has established Permissible Exposure Limits (PELs) for various substances. These published values **are** legal standards. OSHA has been noted as adopting some of the TLVs® as their PELs. Substances listed by OSHA as having PELs must be used to avoid exposing anyone above OHSA's established levels. These PEL's may be found in 29 CFR 1910 Subpart Z. A copy of the tables listing the substances regulated by OSHA found in that subpart are included in this laboratory safety plan under Appendix K.

The best way to avoid exposure to toxic vapors, mists, gases, and dusts is to:

1. Prevent the escape of such materials into the working atmosphere.

2. Ensure adequate ventilation by the use of exhaust hoods and other local ventilation.

3. Never smell chemicals of unknown toxicity.

B.INGESTION

Many of the chemicals used in the laboratory are extremely dangerous when they enter the mouth and are swallowed. The relative acute toxicity of a particular substance may be determined by its LD_{50}. LD_{50} is defined as the quantity of material that, when ingested or applied to the skin in a single dose, will cause the death of 50% of the test animals. It is usually expressed in grams or milligrams per kilogram of body weight. In addition, many chemicals may damage the tissues of the mouth, nose, throat, lungs and gastrointestinal tract and produce systemic poisoning if absorbed through the tissues.

To prevent entry of toxic chemicals into the mouth:

1. Laboratory workers should wash their hands before eating, smoking, or applying cosmetics (including lip balm).

2. Laboratory workers should wash hands immediately after use of any toxic substance.

3. Laboratory workers should wash hands before leaving the laboratory (even for short periods of time).

4. Food and drink should not be stored or consumed in areas where chemicals are being used.

5. Cigarettes, cigars and pipes be used in areas where chemicals are being used.

6. Chemicals should not be tasted.

7. Pipetting and siphoning of liquids should not be done by mouth.

C.CONTACT WITH SKIN AND EYES (ABSORPTION)

Contact with the skin is a frequent mode of chemical injury. A common result of skin contact is a localized irritation, but an appreciable number of materials are absorbed through the skin with sufficient rapidity to produce systemic poisoning. The main portals of entry for chemicals through the skin are the hair follicles, sebaceous glands, sweat glands, and cuts or abrasions of the outer layers of the skin. The follicles and glands are abundantly supplied with blood vessels, which facilitates the absorption of chemicals into the body.

Contact of chemicals with the eyes is of particular concern because these organs are so sensitive to irritants. Few substances are innocuous in contact with the eyes; most are painful and irritating, and a considerable number are capable of causing burns and loss of vision. Alkaline materials, phenols, and strong acid are particularly corrosive and can cause permanent loss of vision. Also, eyes are very vascular and provide for rapid absorption of many chemicals.

1. Skin and eye contact with chemicals should be avoided through use of appropriate protective equipment.

2. All persons in the laboratory should wear safety glasses.

3. Face shields, safety goggles, shields, and similar devices provide better protection for the eyes and should be used wherever possible.

4. Protection against skin contact may be obtained by use of gloves, laboratory coats, tongs, and other protective devices.

5. Spills should be cleaned up promptly with the proper equipment.

6. In the event of skin contact, the affected areas should be flushed with water for 15 minutes and medical attention should be sought if any symptoms persist.

7. In the event of eye contact, the eye(s) should be flushed with water for <u>15 minutes</u> and medical attentions sought <u>whether or not</u> symptoms persist.

D.INJECTION

Exposure to toxic chemicals by injection seldom occurs in the chemical laboratory in the normal sense of hypodermic needles used in medicine. However, injection can inadvertently occur through mechanical injury from glass or metal contaminated with chemicals or when chemicals are being handled in syringes.

1. Wear protective clothing such as gloves or laboratory coat when handling sharp objects or broken glass.

ACUTE AND CHRONIC TOXICITY

The toxicity of a material is due to its ability to damage or interfere with the metabolism of living tissue. An acutely toxic substance can cause damage as the result of a single or short-duration exposure. A chronically toxic substance causes damage after repeated or long-duration exposure or that becomes evident only after a long latency period. This includes all carcinogens and many metals and their compounds. Chronic toxins are particularly insidious because of their long latency periods. The cumulative effects of low exposures may not be apparent for many years. Some chemicals can be either acutely or chronically toxic depending on the degree of exposure.

1. If you are unsure whether or not any substance is toxic (acutely or chronically), it should be regarded as toxic unless reliable information showing otherwise is received.

2. All new and untested chemicals should be regarded as toxic until proven otherwise.

EMBRYOTOXINS AND TERATOGENS

Embryotoxins are substances that act during pregnancy to cause adverse effects on the fetus. These effects include embryolethality (death of the fertilized egg, embryo, or fetus), malformations (teratologic effects), retarded growth, and postnatal functional deficits.

Because the period of greatest susceptibility to embryotoxins is the first 8-12 weeks of pregnancy, which includes a period when a woman may not know she is pregnant, women of child-bearing potential should take care to avoid skin contact with all chemicals. The following procedures are recommended to be followed routinely by women of child bearing potential in working with chemicals requiring special control due to embryotoxic or teratogenic properties:

1. Each use should be reviewed for particular hazards by the research or laboratory supervisor, who will decide whether special procedures are warranted or whether warning signs should be posted. Consultation with the campus Chemical Hygiene Officer or other appropriate safety personnel should occur for proper incorporation into this plan.

2. In cases of continued use of a known embryotoxin or teratogen, the operation should be reviewed annually by Department chairperson in conjunction with the campus Chemical Hygiene Officer.

3. Embryotoxins or teratogens requiring special control should be stored in an adequately ventilated area. All containers should be labeled in a clear manner such as the following: EMBRYOTOXIN: READ SPECIFIC PROCEDURES FOR USE.

4. If the storage container is breakable, it should be kept in an impermeable, unbreakable secondary container having sufficient capacity to retain the material should the primary container break.

5. Women of child bearing potential should take adequate precautions to guard against spills and splashes.

6. Operations should be carried out using impermeable containers and in adequately ventilated areas (such as in laboratory ventilation hoods).

7. Appropriate safety apparel, especially gloves, should be worn.

8. All hoods, glove boxes, or other essential engineering controls should be known to be operating at required efficiency before work is started.

9. Supervisors should be notified of all incidents of exposure or spills of embryotoxins requiring special control.

10. A qualified physician should be consulted about any exposures of women of child-bearing potential above the acceptable level, ie. skin contact or any inhalation.

ALLERGENS

A wide variety of substances can produce skin and lung hypersensitivity. Examples include such common substances as diazomethane, chromium, nickel, bichromates, formaldehyde, isocyanates, and certain phenols. Because of this variety and the varying response of individuals, suitable gloves and adequate ventilation should be used whenever contact with products of unknown activity is probable.

CORROSIVE CHEMICALS

Major classes of corrosive chemicals are strong acids and bases, dehydrating agents and oxidizing agents. Some chemicals (e.g. sulfuric acid) belong to more than one class. Inhalation of vapors or mists of these substances can cause severe bronchial irritation. These chemicals erode the skin and the respiratory epithelium and are particularly damaging to the eyes.

Strong Acids

All concentrated strong acids can damage the skin and eyes. Exposed areas should be flushed promptly with water. Nitric, chromic, and hydrofluoric acids are especially damaging because of the types of burns they inflict. Hydrofluoric acid, which produces slow healing, painful burns, should be used only after thorough familiarization with recommended handling procedures.

Strong Bases

The common strong bases are potassium hydroxide, sodium hydroxide, and ammonia. Ammonia is a severe bronchial irritant and should always be used in a well-ventilated area. The metal hydroxides are extremely damaging to the eyes. Should exposure occur, the affected areas should be washed at once with copious quantities of water and an ophthalmologist should evaluate the need for further treatment.

Dehydrating Agents

The strong dehydrating agents include concentrated sulfuric acid, sodium hydroxide, phosphorus pentoxide and calcium oxide. Because much heat is evolved on mixing these substances with water, mixing should always be done by adding the agent to water to avoid violent reaction and spattering. These substances cause severe burns when in contact with the skin due to their affinity for water. Affected areas should be washed promptly with large volumes of water for at least 15 minutes.

Oxidizing Agents

In addition to their corrosive properties, powerful oxidizing agents such as perchloric and chromic acids (sometimes used as cleaning solution), present fire and explosion hazards on contact with organic compounds and other oxidizable substances. The hazards associated with the use of perchloric acid are especially severe, it should handled only after familiarization with recommended procedures. Strong oxidizing agents should be stored and used in glass or other inert containers (preferably unbreakable), and corks and rubber stoppers should not be used. Reaction vessels containing significant quantities of these reagents should be heated by using fiberglass mantles or sand baths rather than oil baths.

TYPES OF HANDLING PROCEDURES

Recommendations for handling procedures for chemicals begin with the admonition that, even for substances of no known significant hazard, it is prudent to observe good laboratory practice, minimizing exposure by working in an exhaust hood and wearing eye and hand protection and a laboratory coat or apron. For the case of substances that present special hazards we call attention to the following procedures for minimizing risk.

For *toxic substances*, the procedures fall into three groups:

1. OSHA has published detailed procedures (29 CFR 1910) for working with substances classified as carcinogens. These standards are more stringent then the procedures outlined in this laboratory safety plan as Procedure A (below). Anyone contemplating work with materials listed below should consult the most current regulations to be advised of the necessary approvals, training, working conditions, monitoring, record keeping, and medical surveillance. In addition, if a laboratory worker anticipates that an OSHA regulated carcinogen might be a product or an impurity in a laboratory process, the regulations should be consulted.

The OSHA list as of July 1989 includes the following substances:

2-Acetylaminofluorene
Acrylonitrile
4-Aminodiphenyl
Asbestos, tremolite, anthophyllite, and actinolite
Benzene
Benzidine
bis-Cholormethyl ether
1,2-dibromo-3-chloropropane
3,3'-Dichlorobenzidine (and its salts)
4-Dimethylaminoazobenzene
Ethyleneimine
Ethylene Oxide
Formaldehyde
Inorganic arsenic
Methyl chloromethyl ether
alpha-Naphthylamine
beta-Napthylamine
4-Nitrobiphenyl
N-Nitrosodimethylamine
beta-Propiolactone
Vinyl Chloride

A carcinogen list produced by the International Agency for Research on Cancer (IARC) that lists both known human carcinogens and suspect human carcinogens may be found in Appendix L.

2. Procedure A (below) should be followed in laboratory operations using those substances believed to be moderately to highly toxic, even when used in small amounts. A substance that has caused cancer in humans or has shown high carcinogenic potency in test animals (but for which a regulatory standard has not been issued by OSHA) will require the use of Procedure A. However, before using

Procedure A, other factors, such as the physical form and volatility of the substance, the kind and duration of exposure, and the amount to be used should also be considered.

3. Procedure B (below) should be followed in laboratory operations using substances for which infrequent, small quantities do not constitute a significant carcinogenic hazard but which can be dangerous to those exposed to high concentrations or repeated doses. A substance that is not known to cause cancer in humans, but which has shown statistically significant, but low carcinogenic potency in animals will require the use of Procedure B.

Many of the general recommendations for safe practices in the laboratory are especially applicable to the handling of corrosive substances. It is also important that attention be given to the use of protective apparel and safety equipment (see Appendices A-2 and A-3). In addition, the storage, disposal, and cleanup of corrosive substances requires special care. Bottles of corrosive liquids should be stored in acid containers or in polyethylene or lead trays or containers large enough to contain the contents of the bottle; most major suppliers will provide acids in plastic-coated glass bottles, which are much less likely to break than ordinary bottles. To ensure that mutually reactive chemicals cannot accidentally contact one another, such substances should not be store in the same trays unless they are in unbreakable, corrosion-resistant secondary containers. In disposal of corrosive substances, care must be taken not to mix them with other potentially reactive wastes. In most cases, spills involving these substances should be contained, carefully diluted with water, and then neutralized.

PROCEDURE B

Before beginning a laboratory operation, each worker is to consult standard compilations (such as SDS/MSDSs) that list toxic properties of known substances and learn what is known about the substances that will be used. The precautions and procedures described below should be followed if any of the substances to be used is known to be highly toxic. These procedures should be followed if the toxicological properties of any of the substances being used or prepared are known to high chronic toxicity (e.g. compounds of heavy metals and strong carcinogens), then the precautions and procedures described below should be supplemented with additional procedures (such as those found in Procedure A) to aid in containing and, ultimately, destroying substances that have high chronic toxicity.

The overall objective of Procedure B is to minimize exposure of the laboratory worker to toxic substances, by any route of exposure, by taking all reasonable precautions. Thus, the general precautions outlined in other appendices should normally be followed whenever a toxic substance is being transferred from one container to another or is being subjected to some chemical or physical manipulation. The following three precautions should **always** be followed:

1. Protect the hands and forearms by wearing either gloves and a laboratory coat or suitable long gloves (gauntlets) to avoid contact of toxic material with the skin.

2. Procedures involving volatile toxic substances and those involving solid or liquid toxic substances that may result in the generation of aerosols should be conducted in a certified hood or other suitable containment device.

3. After working with toxic materials, wash the hands and arms immediately. Never eat, drink, smoke, chew gum, apply cosmetics (including lip balms), take medicine, or store food in areas where toxic substances are being used.

These standard precautions will provide laboratory workers with good protection from most toxic substances. In addition, records that include amounts of materials used and names of workers involved should be kept as part of the laboratory notebook record of the experiment. To minimize hazards from accidental breakage of apparatus or spills of toxic substances in the hood, containers of such substances should be stored in pans or trays made of polyethylene or other chemically resistant materials and apparatus should be mounted above trays of the same type of material. Alternatively, the working surface of the hood can be fitted with a removable liner of adsorbent plastic-backed paper. Such procedures will contain spilled toxic substances in a pan, tray or adsorbent liner and greatly simplify subsequent cleanup and disposal. Vapors that are discharged from the apparatus should be trapped or condensed to avoid adding substantial amounts of toxic vapor to the hood exhaust air. Areas where toxic substances are being used and stored should have restricted access, and special warning signs should be posted if a special toxicity hazard exists.

The general waste-disposal procedures described in the Hazardous Waste Disposal Program should be followed. However, certain additional precautions should be observed when waste materials are known to contain substances of moderate or high toxicity. Volatile toxic substances should never be disposed of by evaporation in the hood. If practical, waste materials and waste solvents containing toxic substances should be decontaminated chemically by some procedure that can reasonably be expected to convert essentially all of the toxic substance to nontoxic substances. If chemical decontamination is not feasible, the waste materials and solvents containing toxic substances should be stored in closed, impervious containers so that personnel handling the containers will not be exposed to their contents. In general, liquid residues should be contained in glass or polyethylene bottles half-filled with vermiculite. All containers of toxic wastes should be suitably labeled to indicate the contents (chemicals and approximate amount) and the type of toxicity hazard that contact may pose. For example, containers of wastes from experiments involving appreciable amounts of weak or moderate carcinogens should carry the warning: CANCER-SUSPECT AGENT. All wastes and residues that have not been chemically decontaminated in the exhaust hood where the experiment was carried out should be disposed of in a safe manner that ensures that personnel are not exposed to the material. (See Hazardous Waste Disposal Program)

The laboratory worker should be prepared for possible accidents or spills involving toxic substances. If a toxic substance contacts the skin, the area should be washed well with water (at least 15 minutes) or a safety shower should be used. If there is a major spill outside the hood, a supplied air full-face respirator should be worn (only by those trained and tested to properly wear one). Contaminated clothing and shoes should be thoroughly decontaminated or disposed of as hazardous waste.

PROCEDURE A

All of the procedures and practices described in Procedure B should be followed when working with substances known to have high chronic toxicity. In addition, when such substances are to be used in quantities in excess of a few milligrams to a few grams (depending on the hazard posed by the particular substance), the additional procedures described below are required. Each laboratory worker's plans for experimental work and for disposing of waste materials should be approved by the laboratory supervisor or department prior to the start of work. Consultation with the campus chemical hygiene officer or other safety coordinators is strongly suggested to ensure that the toxic material is effectively contained during the experiment and that waste materials are disposed of in a safe manner. Substances in this high-chronic-toxicity category include certain heavy metal compounds (e.g., dimethylmercury and nickel carbonyl) and compounds normally classified as strong (select) carcinogens. Examples of compounds frequently considered to be strong carcinogens include the following: benzo[a]pyrene; 3-methylcholanthrene; 7,12-dimethylbenz[a]anthracene; dimetyhlcarbamoyl chloride; hexamethylphosphoramide; 2-nitronaphthalene; propane sultone; many N-nitrosamines; many N-nitrosamides; bis(chloromethyl)ether; aflatoxin B_1; and 2-acetylaminofluorene.

An accurate record of the amounts of such substances being stored and of the amounts used, dates of use, and names of users should be maintained. It may be appropriate to keep such records as part of the record of experimental work in the laboratory worker's research notebook, but it must be understood that the research or laboratory supervisor is responsible for ensuring that the records are kept. Any volatile substances having high chronic toxicity should be stored in a ventilated storage area and in a secondary tray or container having sufficient capacity to contain the material should the primary container accidentally break. All containers of substances in this category should have labels that identify the contents and include a warning such as the following: WARNING! HIGH CHRONIC TOXICITY OR CANCER-SUSPECT AGENT. Storage areas for substances in this category should have limited access, and special signs should be posted if a special toxicity hazard exists. Any area used for storage of substances of high chronic toxicity should be maintained under negative pressure with respect to surrounding areas.

All experiments with and transfers of such substances or mixtures containing such substances should be done in a controlled area. (NOTE: A controlled area as defined in this plan is a laboratory, a portion of a laboratory, or a facility such as an exhaust hood or a glove box that is designated for the use of highly toxic substances. Its use need not be restricted to the handling of toxic substances if all personnel who have access to the controlled area are aware of the nature of the substances being used and the precautions that are necessary.) When a negative-pressure glove box in which work is done through attached gloves is used, the ventilation rate in the glove box should be at least two volume changes per hour, the pressure should be at least 0.5 inches of water lower than the external environment, and the exit gases should be passed through a trap or HEPA filter. Positive-pressure glove boxes are normally used to provide an inert anhydrous atmosphere. IF these glove boxes are used with highly toxic compounds, then the box should be thoroughly checked for leaks before each use and the exit gases should be passed through a suitable trap or filter. Laboratory vacuum pumps used with substances having high chronic toxicity should be protected by high-efficiency scrubbers or HEPA filters and vented into an exhaust hood. Motor-driven vacuum pumps are recommended because they are easy to decontaminate (NOTE: Decontamination of a vacuum pump should be carried out in an exhaust hood). Controlled areas should be clearly marked with a conspicuous sign such as the following: WARNING; TOXIC SUBSTANCE IN USE or CANCER-SUSPECT AGENT: AUTHORIZED PERSONNEL ONLY. Only authorized and instructed personnel should be allowed to work in or have access to controlled areas.

Proper gloves (see Appendix A-2) should be worn when transferring or otherwise handling substances or solutions of substances having high chronic toxicity. In some cases, the laboratory worker or the research supervisor may deem it advisable to use other protective apparel, such as an apron of reduced permeability covered by a disposable coat. Extreme precautions such as these might be taken, for example, when handling large amounts of certain heavy metals and their derivatives or compounds known to be potent carcinogens. Surfaces on which high chronic toxicity substances are handled should be protected from contamination by using chemically resistant trays or pans that can be decontaminated after the experiment or by using dry absorbent, plastic backed paper that can be disposed of after use.

On leaving a controlled area, laboratory workers should remove any protective apparel that has been used and thoroughly wash hands, forearms, face, and neck. If disposable apparel or absorbent paper liners have been used, these items should be placed in a closed and impervious container that should then be labeled in some manner such as the following: CAUTION: CONTENTS CONTAMINATED WITH SUBSTANCE

OF HIGH CHRONIC TOXICITY. Non-disposable protective apparel should be thoroughly washed, and containers of disposable apparel and paper liners should be incinerated.

Wastes and other contaminated materials form an experiment involving substances of high chronic toxicity should be collected together with the washings from flasks and such and either decontaminated chemically or placed in closed, suitably labeled containers for incineration away from the controlled area. If chemical decontamination is to be used, a method should be chosen that can reasonably be expected to convert essentially all of the toxic materials into nontoxic materials.

In the event that chemical decontamination is not feasible, wastes and residues should be placed in an impervious container that should be closed and labeled in some manner such as the following: CAUTION: COMPOUNDS OF HIGH CHRONIC TOXICITY or CAUTION: CANCER-SUSPECT AGENT. Transfer of contaminated wastes from the controlled area to the incinerator should be done under the supervision of authorized personnel and in such a manner as to prevent spill or loss. In general, liquid wastes containing such compounds should be place in glass or polyethylene (usually preferable) bottles half filled with vermiculite and these should be transported in plastic or metal pails of sufficient capacity to contain the material in case of accidental breakage of the primary container.

Normal laboratory work should not be resumed in a space that has been used as a controlled area until it has been adequately decontaminated. Work surfaces should be thoroughly washed and rinsed. If experiments have involved the use of finely divided solid materials, dry sweeping should not be done. In such cases, surfaces should be cleaned by wet mopping or by use of a vacuum cleaner equipped with a high efficiency particulate air (HEPA) filter. All equipment (e.g. glassware, vacuum traps, and containers) that is known or suspected to have been in contact with substances of high chronic toxicity should be washed and rinsed before they are removed from the controlled area.

In the event of continued experimentation with a substance of high chronic toxicity (i.e. if a worker regularly uses toxicologically significant quantities of such a substance three times a week), a qualified physician should be consulted to determine whether it is advisable to establish a regular schedule of medical surveillance or biological monitoring.

Appendix A-6

WORKING WITH SUBSTANCES THAT HAVE FLAMMABILITY OR EXPLOSIBILITY HAZARDS

{The following was extracted and adapted from Prudent Practices for Handling Hazardous Chemicals in Laboratories (National Research Council, 1981}

Flammable substances are among the most common of the hazardous materials found in laboratories. However, the ability to vaporize, ignite, and burn or to explode varies with the specific type or class of substance. Prevention of fires and explosions requires knowledge of the flammability characteristics of combustible materials likely to be encountered under various conditions of use (or misuse) and of the appropriate procedures to use in handling such substances.

FLAMMABILITY AND EXPLOSIBILITY OF MIXTURES OF AIR WITH GASES, LIQUIDS AND DUSTS

PROPERTIES OF FLAMMABLE SUBSTANCES

Flammable substances are those that readily catch fire and burn in air. A flammable liquid does not itself burn; it is the vapors from the liquid that burn. The rate at which different liquids produce flammable vapors depends on their vapor pressure, which increases with temperature. The degree of fire hazard depends also on the ability to form combustible or explosive mixtures with air, the ease of ignition of these mixtures, and the relative densities of the liquid with respect to water and of the gas with respect to air. These concepts can be evaluated and compared in terms of a number of properties.

Flash Point

An open beaker of diethyl ether set on the laboratory bench next to a Bunsen burner will ignite, whereas a similar beaker of diethyl phthalate will not. The difference in behavior is due to the fact that ether has a much lower flash point. The flash point is the lowest temperature, as determined by standard tests, at which a liquid gives off a vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid within the test vessel. Many common laboratory solvents and chemicals have flash points that are lower than room temperature.

Ignition Temperature

The ignition temperature (autoignition temperature) of a substance, whether solid, liquid, or gaseous, is the minimum temperature required to initiate or cause self-sustained combustion independent of the heat source. A steam line or a glowing light bulb may ignite carbon disulfide (which has an ignition temperature of 80°C). Diethyl ether (ignition temperature 160°C) can be ignited by the surface of a hot plate.

Limits of Flammability

A flammable liquid may be above its flash point and yet not ignite in the presence of an adequate energy source. The explanation for this phenomenon lies in the composition of a fuel-air mixture that may be too lean or too rich for combustion.

Each flammable gas and liquid (as a vapor) has two fairly definite limits defining the range of concentrations in mixtures with air that will propagate flame and explode.

The ***lower flammable limit*** [lower explosive limit (LEL)] is the minimum concentration (percent by volume) of the vapor in air below which a flame is not propagated when an ignition source is present. Below this concentration, the mixture is too lean to burn. The ***upper flammable limit*** [upper explosive limit (UEL)] is the maximum concentration (percent by volume) of the vapor in air above which a flame is not propagated. Above this concentration, the mixture is too rich to burn. The flammable range (explosive range) consists of all concentrations between temperature and in oxygen rich atmospheres.

The limitations of the flammability range, however, provide little margin of safety from the practical point of view because, when a solvent is spilled in the presence of an energy source, the LEL is reached very quickly and a fire or explosion will ensue before UEL can be reached.

Spontaneous Ignition

Spontaneous ignition or combustion takes place when a substance reaches its ignition temperature without the application of external heat. The possibility of spontaneous combustion should be considered, especially when materials are stored or disposed of. Materials susceptible to spontaneous combustion include oily rags, dust accumulations, organic materials mixed with strong oxidizing agents (such as nitric acid, chlorates, permanganates, peroxides, and persulfates), alkali metals such as sodium and potassium, finely divided pyrophoric metals, and phosphorus.

The flash points, boiling points, flammable limits, and ignition temperatures are often found on a substance's material safety data sheet (MSDS). Remember that the values indicating the properties of flammable substances are based on standard test methods for which the conditions may be very different from those encountered in practical use. **Large safety factors should be applied**. For example, the published flammable limits of vapors are for uniform mixtures with air. In a real situation, point concentrations that are much higher than average may exist. Thus, it is good practice to set the maximum allowable concentration for safe working conditions at some fraction of the published lower explosive limit (LEL); 20% is a commonly accepted value.

HANDLING FLAMMABLE LIQUIDS

Among the most hazardous liquids are those that have flash points at room temperature or lower, particularly if their range of flammability is broad. Materials having flash points higher than the maximum ambient summer temperature do not ordinarily form ignitable mixtures with air under normal (unheated) conditions but many commonly used substances are potentially very hazardous, even under relatively cool conditions.

Sources of Ignition

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

1. A concentration of flammable gas or vapor that is within the flammable limits of the substance

2. an oxidizing atmosphere, usually air

3. a source of ignition

Removal of any of the three will prevent the start of a fire or extinguish an existing fire. In most situations, air cannot be excluded. The problem, therefore, usually resolves itself into preventing the coexistence of flammable vapors and an ignition source. Because spillage of a flammable liquid is always a possibility, strict control of ignition sources is mandatory

Many sources - electrical equipment, open flames, static electricity, burning tobacco, lighted matches, and hot surface - can cause ignition of flammable substances. When these materials are used in the laboratory, close attention should be given to all potential sources of ignition in the vicinity. The vapors of all flammable liquids are heavier than air and capable of traveling considerable distances. This possibility should be recognized, and special note should be taken of ignition sources at a lower level than that at which the substance is being used.

Flammable vapors from massive sources such as spillages have been known to descend into stairwells and elevator shafts and ignite on a lower story. If the path of vapor within the flammable range is continuous, the flame will propagate itself from the point of ignition back to its source.

Metal lines and vessels discharging flammable substances should be properly bonded and grounded to discharge static electricity. When nonmetallic containers (especially) plastic are used, the bonding can be made to the liquid rather than to the container. When no solution to the static problem can be found, then all processes should be carried out as slowly as possible to give the accumulated charge time to disperse.

Use of Flammable Substances

The basic precautions for safe handling of flammable materials include the following:

1. Flammable substances should be handled only in areas free of ignition sources.

2. Flammable substances should never be heated by using an open flame. Preferred heat sources include steam baths, water baths, oil baths, heating mantles, and hot air baths.

3. When transferring flammable liquids in metal equipment, static-generated sparks should be avoided by bonding and the use of ground straps.

4. Ventilation is one of the most effective ways to prevent the formation of flammable mixtures. An exhaust hood should be used whenever appreciable quantities of flammable substances are transferred from one container to another, allowed to stand in open containers, heated in open containers, or handled in any other way.

FLAMMABLE OR EXPLOSIVE GASES AND LIQUEFIED GASES

Compressed or liquefied gases present hazards in the event of fire because the heat will cause the pressure to increase and may rupture the container. Leakage or escape of flammable gases can produce an explosive atmosphere in the laboratory. Acetylene, hydrogen, ammonia, hydrogen sulfide, and carbon monoxide are especially hazardous. Acetylene and hydrogen have very wide flammability limits, which adds greatly to their potential fire and explosion hazard.

Even if it is not under pressure, a substance is more concentrated in the form of a liquified gas than in the vapor phase and may evaporate extremely rapidly. Oxygen, in particular, is an extreme hazard; liquified air is almost as dangerous [if allowed to boil freely, it will have an increasing concentration of oxygen (bp -183°C) because the nitrogen (bp -196°C) will boil away first]; and even liquid nitrogen, if it has been standing around for some time, will have absorbed enough oxygen to require careful handling. When a liquefied gas is used in a closed system, pressure may build up, so that adequate venting is required. If the liquid is flammable (e.g. hydrogen), explosive concentrations may develop. Any, or all, of the three problems, flammability, toxicity, and pressure buildup, may become serious.

DUSTS

Suspensions of oxidizable particles (such as magnesium powder, zinc dust, or flowers of sulfur) in the air constitute a powerful explosive mixture. Care should be exercised in handling these materials to avoid exposure to ignition sources.

HIGHLY REACTIVE CHEMICALS AND EXPLOSIVES

When the term "routine chemical reaction" is used, it usually implies a safe reaction; safe because the reaction rate is relatively slow or can be easily controlled. Highly reactive chemicals can lead to reactions that differ from routine mainly in the rate at which they progress. Reaction rates almost always increase rapidly as the temperature increases. If the heat evolved in a reaction is not dissipated, the reaction rate can increase until an explosion results. This factor must be considered, particularly when scaling up experiments, so that sufficient cooling and surface for heat exchange can be provided.

Some chemicals decompose when heated. Slow decomposition may not be noticeable on small scale but on a large scale, or if the evolved heat and gases are confined, an explosive situation can develop. The heat-initiated decomposition of some substances, such as certain peroxides, is almost instantaneous.

Light, mechanical shock, and certain catalysts are also initiators of explosive reactions. Hydrogen and chlorine react explosively in the presence of light. Examples of shock-sensitive materials include acetylides, azides, organic nitrates, nitro compounds, and many peroxides. Acids, bases, and other substances catalyze the explosive polymerization of acrolein, and many metal ions can catalyze the violent decomposition of hydrogen peroxide.

Not all explosions result from chemical reactions. A dangerous, physically caused explosion can occur if a hot liquid (such as oil) is brought into sudden contact with a lower-boiling point on (such as water). The instantaneous vaporization of the lower-boiling point substance can be hazardous to personnel and destructive to equipment.

Any given sample may be just atypical enough (by virtue of impurities and such) to be dangerous. Furthermore, the hazard is associated not with the total energy released, by rather with the amazingly high rate of a detonation reaction. A high-order explosion of even milligram quantities can drive small fragments of glass or other matter deep into the body.

ORGANIC PEROXIDES

POTENTIAL PEROXIDE FORMING CHEMICALS

acetalcyclohexane

decahydronapthalenediactylene

dicyclopentadienedethyl ether

diethylene glycoldimethyl ether

dioxanedivinyl acetylene

ether (glyme)ethylene glycol diemethy ether

tetra hydronaphthalenemethyl acetylene

isospropyl ethertetrahydrofuran

sodium amidevinyl ethers

vinyldene chloride

Table B-5 1

Organic peroxides are a special class of compounds that have unusual stability problems that make them among the most hazardous substances normally handled in laboratories. As a class, they are low-power explosives, hazardous because of their extreme sensitivity to shock, sparks, or other forms of accidental ignition. Many peroxides that are routinely handled in laboratories are far more sensitive to shock than most primary explosives (e.g. TNT). Peroxides have a specific half-life, or rate of decomposition, under any given set of conditions. A low rate of decomposition may autoaccelerate and cause a violent explosion, especially in bulk quantities of peroxide. These compounds are sensitive to heat, friction, impact, and light, as well as to strong oxidizing and reducing agents. All organic peroxides are highly flammable, and fires involving bulk quantities of peroxides should be approached with extreme caution. A peroxide present as a contaminant in a reagent or solvent can change the course of a planned reaction.

Types of compounds known to form peroxides include the following:

1. Aldehydes

2. Ethers, especially cyclic ether and those containing primary and secondary alcohol groups, form dangerous peroxides on exposure to air and light.

a) Several acceptable colorimetric tests for peroxides in ether (e.g. Jorissen reagent) are available.

b) If a test is positive, the contaminated liquid can be filtered through a column of chromatographic, basic grade aluminum oxide until the test is negative. The contaminated alumina should be discarded properly.

c) Ethers must never be distilled unless known to be free of peroxides.

d) Containers of diethyl or diisopropyl ether should be dated when they are opened. If they are still in the laboratory after 1 month, the ether should be tested for peroxides before use. If peroxides are found, the material should be decontaminated or destroyed.

3. Compounds containing benzylic hydrogen atoms - Such compounds are especially susceptible to peroxide formation if the hydrogens are on tertiary carbon atoms.

4. Compounds containing the allyic ($CH_2=CHCH_2R$) structure, including most alkenes.

5. Vinyl and vinyldene compounds

Specific chemicals that can form dangerous concentrations of peroxides on long exposure to air are cyclohexene, cyclooctene, decalin, *p*-dioxane, diethyl ether, diisopropyl ether, tetrahydrofuran, and tetralin.

Precautions for handling peroxides include the following:

1. The quantity of peroxide should be limited to the minimum amount required. Unused peroxides should not be returned to the container.

2. All spills should be cleaned up immediately. Solutions of peroxides can be absorbed on vermiculite.

3. The sensitivity of most peroxides to shock and heat can be reduced by dilution with inert solvents, such as aliphatic hydrocarbons. However, toluene is known to induce the decomposition of diacyl peroxides.

4. Solutions of peroxides in volatile solvents should not be used under conditions in which the solvent might be vaporized because this will increase the peroxide concentration in the solution.

5. Metal spatulas should not be used to handle peroxides because contamination by metals can lead to explosive decomposition. Ceramic or wooden spatulas may be used.

6. Smoking, open flames, and other sources of heat should not be permitted near peroxides.

7. Friction, grinding and all forms of impact should be avoided near peroxides (especially solid ones). Glass containers that have screw-cap lids or glass stoppers should not be used. Polyethylene bottles that have screw-cap lids may be used.

8. To minimize the rate of decomposition, peroxides should be stored at the lowest possible temperature consistent with their solubility or freezing point. Liquid or solutions of peroxides should not be stored at or lower than the temperature at which the peroxide freezes or precipitates because peroxides in these forms are extremely sensitive to shock and heat.

Disposal of Peroxides

Pure peroxides should never be disposed of directly. Peroxides must be diluted before disposal.

Small quantities (25 g or less) of peroxides are generally disposed of by dilution with water to a concentration of 2% or less and then transfer of the solution to a polyethylene bottle containing an aqueous solution of a reducing agent, such as ferrous sulfate or sodium bisulfite. The material can then be handled like any other waste chemical; however, it must not be mixed with other chemicals for disposal. Spilled peroxides should be absorbed on vermiculite as quickly as possible. The vermiculite-peroxide mixture can be burned directly or may be stirred with a suitable solvent to form a slurry that can be treated as described above. Organic peroxides should never be flushed down the drain.

Large quantities (more than 25 g) of peroxides require special handling. Each case should be considered separately, and handling, storage, and disposal procedures should be determined by the physical and chemical properties of the particular peroxide.

SOME ADDITIONAL EXPLOSIVE COMPOUNDS

A compound is apt to be explosive if its heat of formation is smaller by more than about 100 cal/g than the sum of the heats of formation of its products. In making this calculation, one should assume a reasonable reaction to yield the most exothermic products.

In general, compounds containing the following functional groups tend to be sensitive to heat and shock: Acetylide, azide, diazo, halamine, nitroso, ozonide, and peroxide.

Compounds containing nitro groups may be highly reactive, especially if other constituents such as halogens are present. Perchlorates, chlorates, nitrates, bromates, chlorites, and iodates, whether organic or inorganic, should be treated with respect, especially at higher temperatures.

HANDLING EXPLOSIVE COMPOUNDS

Explosive chemicals decompose under conditions of mechanical shock, elevated temperature, or chemical action with forces that release large volumes of gases, heat, toxic vapors, or combinations thereof. Various state and federal regulations exist covering the transportation, storage, and use of explosives. These regulations should be consulted before explosives and related dangerous materials are used in the laboratory.

Explosive materials should be brought into the laboratory only as required and then in the smallest quantities adequate for the experiment being conducted. Explosives should be segregated from other materials that could create a serious hazard to life or property should an accident occur.

The handling of highly energetic substances without injury demands attention to the most minute detail. The unusual nature of work involving such substances requires special safety measures and handling techniques that must be thoroughly understood and followed by all person involved. The practices listed below are a guide for use in any laboratory operation that might involve explosive materials.

Personal Protective Apparel (see Appendix A-2)

This includes the following items:

1. Safety glasses that have a cup-type side shield made of a light, clear plastic material affixed to the frame should be worn by all laboratory personnel.

2. A face shield that has a "snap-on" throat protector in place should be worn at all times that the worker is in a hazardous, exposed position [e.g., when operating or manipulating synthesis systems, when bench shields are moved aside, or when handling or transporting such products].

3. Gloves should be worn whenever it is necessary to reach behind a shielded area while a hazardous experiment is in progress or when handling adducts or gaseous reactants [the yellow "electrical" lineman's gloves afford good protection against 2 g quantity detonations in glass provided the detonation is 7.5cm (3 in) away; however, such a detonation in contact with a gloved hand would cause severe injury and probable loss of fingers].
4. Laboratory coats should be worn at all times while in explosives laboratories. They should be of a slow burning material and fitted with quick release cloth buttons (these coats help reduce minor injuries from flying glass and reduce the possibility of injury from an explosive flash.).

Protective Devices (see Appendix A-3)

Barriers such as shields, barricades, and guards should be used to protect personnel and equipment from injury or damage. The barrier should completely surround the hazardous area. On benches and hoods, a 0.25 inch acrylic sliding shield effectively protects a worker from glass fragments resulting from a laboratory scale detonation. The shield should be closed whenever hazardous reactions are in progress or whenever hazardous materials are being temporarily stored. Such shielding is not effective against metal shrapnel.

Dry boxes should be fitted with safety glass windows overlaid with 0.25 inch thick acrylic. This protection is adequate against an internal 5 g quantity detonation. The problem of hand protection, however, still remains, although electric lineman's gloves over the rubber dry box gloves offer some additional protection. Other safety devices, as required, should be used in conjunction with the gloves (e.g., tongs and lab-jack turners).

Armored hoods or barricades made with extra thick (1.0 inch) polyvinyl butyral resin shielding and heavy metal walls give complete protection against detonations not in excess of the acceptable 20 g limit. These hoods are designed for use with 100 g of material, but an arbitrary 20 g limit is usually set because of the noise level in the event of detonation. Such hoods should be equipped with mechanical hands that enable the operator to remotely manipulate equipment and handle adduct containers. A sign, such as **CAUTION: NO ONE MAY ENTER AN ARMORED HOOD FOR ANY REASON DURING THE COURSE OF A HAZARDOUS OPERATION** should be posted.

Miscellaneous protective devices such as both long and short handled tongs for holding or manipulating hazardous items at a safe distance and remote-control equipment (e.g., mechanical arms, stopcock turners, lab-jack turners, and remote cable controllers) should be available as required to prevent exposure of any part of the body to injury.

Reaction Quantities

In conventional explosives laboratories, no more than 0.5 g of product should be prepared in a single run. During the actual reaction period, no more than 2 g of reactants should be present in the reaction vessel. This means that the diluent, the substrate, and the energetic reactant must all be considered when determining the total explosive power of the reaction mixture. Special reviews should be established to examine operational and safety problems involved in scaling up a reaction in which an explosive substance is used.

Reaction Operations

Various heating methods may be used. The most common are heating tapes and mantles and sand, water, steam, and silicone oil baths. Hair dryers (heat guns) can be used for certain operations; however, their use should be prohibited when a flammable vapor potential is present. All controls for heating and stirring equipment should be operable from outside the shielded area.

Vacuum pumps should carry tags indicating the date of the most recent oil change. Oil should be changed once a month (sooner, if it is known that the oil has been exposed to reactive gases). All pumps should either be vented into a hood or trapped. Vent lines may be Tygon^R, rubber, or copper. If Tygon or rubber lines are used, they should be supported so that they do not sag.

When potentially explosive materials are being handled, the area should be posted with a sign such as **WARNING: VACATE THE AREA AT THE FIRST SIGN OF ODOR. STAY OUT UNTIL THE VENTILATION SYSTEM HAS CLEARED THE AIR.**

When condensing explosive gases, the temperature of the bath and the effect on the reactant gas of the condensing material selected must be determined experimentally. Very small quantities should be used because detonations may occur. In all cases, a shielded Dewar flask should be used when condensing reactants. Maximum quantity limits should be observed. Heating baths of flammable materials is prohibited.

OTHER SPECIFIC CHEMICAL HAZARDS THAT FREQUENTLY LEAD TO FIRES OR EXPLOSIONS

Acetylenic compounds - are explosive in mixtures of 2.5-80% with air. At pressures of 2 or more atmospheres, acetylene (C_2H_2) subjected to an electrical discharge or high temperature decomposes with explosive violence. Dry acetylides detonate on receiving the slightest shock.

Aluminum chloride ($AlCl_3$) should be considered a potentially dangerous material. If moisture is present, there may be sufficient decomposition [to give hydrogen chloride (HCL)] to build up considerable pressure. If a bottle is to be opened after long standing, it should be completely enclosed in a heavy towel.

Ammonia (NH_3) reacts with iodine to give nitrogen triiodide, which is explosive, and with hypochlorites to give chlorine. Mixtures of NH_3 and organic halides sometimes react violently when heated under pressure.

Dry benzoyl peroxide ($(C_6H_5CO_2)_2$) is easily ignited and sensitive to shock. It decomposes spontaneously at temperatures above 50 C. It is reported to be desensitized by addition of 20% water.

Carbon disulfide (CS_2) is both very toxic and very flammable; mixed with air its vapors can be ignited by a steam bath or pipe, a hot plate, or a glowing light bulb.

Chlorine (CL_2) may react violently with hydrogen (H_2) or with hydrocarbons when exposed to sunlight.

Chromium trioxide-pyridine complex (CrO_3-C_5H_5N) may explode if the CrO_3 concentration is too high. The complex should be prepared by addition of CrO_3 to excess C_5H_5N.

Diazomethane (CH_2N_2) and related compounds should be treated with extreme caution. They are very toxic, and the pure gases and liquids explode readily. Solutions in ether are safer from this standpoint.

Dimethyl Sulfoxide [$(CH_3)_2SO$ decomposes violently on contact with a wide variety of active halogen compounds. Explosions from contact with active metal hydrides have been reported. Its toxicity is still unknown, but it does penetrate and carry dissolved substances through the skin membrane.

Dry ice should not be kept in a container that is not designed to withstand pressure. Containers of other substances stored over dry ice for extended periods generally absorb carbon dioxide (CO_2) unless they have been sealed with care. When such containers are removed from storage and allowed to come rapidly to room temperature, the CO_2 may develop sufficient pressure to burst with explosive violence. On removal of such containers from storage, the stopper should be loosened or the container itself should be wrapped in towels and kept behind a shield. Dry ice can produce serious burns (this is also true for all types of cooling baths).

Drying agents - Ascarite^R should not be mixed with phosphorus pentoxide (P_2O_5) because the mixture may explode if it is warmed with a trace of water. Because the cobalt salts used as moisture indicators in some drying agents may be extracted by some organic solvents, the use of these drying agents should be restricted to gases.

Diethyl, diisopropyl, and other ethers (particularly the branched-chain type) sometimes explode during heating or refluxing because of the presence of peroxides. Ferrous salts of sodium bisulfite can be used to decompose these peroxides, and passage over basic active alumina will remove most of the peroxidic material. In general, however, old samples of ethers should be discarded.

Ethylene oxide (C_2H_4O) has been known to explode when heated in a closed vessel. Experiments using ethylene oxide under pressure should be carried out behind suitable barricades.

Halogenated compounds - Chloroform ($CHCl_3$), carbon tetrachloride (CCl_4), and other halogenated solvents should not be dried with sodium, potassium, or other active metal; violent explosions are usually the result of such attempts. Many halogenated compounds are toxic.

Hydrogen peroxide (H_2O_2) stronger than 3% can be dangerous; in contact with the skin, it may cause severe burns. Thirty percent H_2O_2 may decompose violently if contaminated with iron, copper, chromium, or other metals or their salts.

Liquid nitrogen cooled traps open to the atmosphere rapidly condense liquid air. Then, when the coolant is removed, an explosive pressure buildup occurs, usually with enough force to shatter glass equipment. Hence, only sealed or evacuated equipment should be so cooled.

Lithium aluminum hydride ($LiAlH_4$) should not be used to dry methyl ethers or tetrahydrofuran; fires from this are very common. The products of its reaction with CO_2 have been reported to be explosive. Carbon dioxide or bicarbonate extinguishers should not be used against $LiAlH_4$ fires, which should be smothered with sand or some other inert substance.

Oxygen tanks - serious explosions have resulted from contact between oil and high-pressure oxygen. Oil should not be used on connections to an O_2 cylinder.

Ozone (O_4) is a highly reactive and toxic gas. It is formed by the action of ultraviolet light on oxygen (air) and therefore, certain ultraviolet sources may require venting in an exhaust hood.

Palladium or platinum on carbon, platinum oxide, Raney nickel, and other catalysts should be filtered from catalytic hydrogenation reaction mixtures carefully. The recovered catalyst is usually saturated with hydrogen and highly reactive and, thus, will enflame spontaneously on exposure to air. Particularly in large scale reactions, the filter cake should not be allowed to become dry. The funnel containing the still moist catalyst filter cake should be put into a water bath immediately after completion of the filtration.

Another hazard in working with such catalysts is the danger of explosion if additional catalyst is added to a flask in which hydrogen is present.

Perchlorates - The use of perchlorates should be avoided wherever possible. Perchlorates should not be used as drying agents if there is a possibility of contact with organic compounds or in proximity to a dehydrating acid strong enough to concentrate the perchloric acid ($HClO_4$) to more than 70% strength (e.g., in a drying train that has a bubble counter containing sulfuric acid). Safer drying agents should be used.

Seventy percent $HClO_4$ can be boiled safely at approximately 200°C, but contact of the boiling undiluted acid or the hot vapor the organic matter, or even easily oxidized inorganic matter (such as compounds of trivalent antimony), will lead to serious explosions. Oxidizable substances must never be allowed to contact $HClO_4$. Beaker tongs, rather than rubber gloves, should be used when handling fuming $HClO_4$. Perchloric acid evaporations should be carried out in a hood that has a good draft. Frequent (weekly) washing our of the hood and ventilator ducts with water is necessary to avoid danger of spontaneous combustion or explosion if this acid is in common use.

Permanganates are explosive when treated with sulfuric acid. When both compounds are used in an absorption train, an empty trap should be placed between them.

Peroxides (inorganic) when mixed with combustible materials, barium, sodium, potassium peroxides form explosives that ignite easily.

Phosphorus (P) (red and white) forms explosive mixtures with oxidizing agents. White P should be stored under water because it is spontaneously flammable in air. The reaction of P with aqueous hydroxides gives phosphine, which may ignite spontaneously or explode.

Phosphorus trichloride (PCL_3) reacts with water to form phosphorous acid, which decomposes on heating to form phosphine, which may ignite spontaneously or explode. Care should be taken in opening containers of PCL_3, and samples that have been exposed to moisture should not be heated without adequate shielding to protect the operator.

Potassium (K) is in general more reactive than sodium; it ignites quickly on exposure to humid air and therefore, should be handled under the surface of a hydrocarbon solvent such as mineral oil or toluene (see sodium).

Residues from vacuum distillations (for example, ethyl palmitate) have been known to explode when the still was vented to the air before the residue was cool. Such explosions can be avoided by venting the still pot with nitrogen, by cooling it before venting, or by restoring the pressure slowly.

Sodium (Na) should be stored in a closed container under kerosene, toluene, or mineral oil. Scraps of Na or K should be destroyed by reaction with n-butyl alcohol. Contact with water should be avoided because Na reacts violently with water to form H_2 with evolution of sufficient heat to cause ignition. Neither carbon dioxide or bicarbonate fire extinguishers should be used on alkali metal fires.

Sulfuric Acid (H_2SO_4) should be avoided, if possible, as a drying agent in desiccators. If it must be used, glass beads should be placed in it to help prevent splashing when the desiccator is moved. The use of H_2SO_4 in melting point baths should be avoided. (Silicone oil should be used.) To dilute H_2SO_4, add the acid slowly to cold water.

Trichloroethylene (Cl_2CCHCl) reacts under a variety of conditions with potassium or sodium hydroxide to form dichloroacetylene, which ignites spontaneously in air and detonates readily even at dry-ice temperatures. The compound itself is highly toxic, and suitable precautions should be taken when it is used as a degreasing solvent.

INCOMPATIBLE CHEMICALS

When transporting, storing, using or disposing of any substance, utmost care must be exercised to ensure that the substance cannot accidently come in contact with another with which it is incompatible. Such contact could result in a serious explosion or the formation of substances that are highly toxic or flammable or both.

The following table may be used as a guide to avoiding accidents involving incompatible substances (from https://ehs.okstate.edu/hazmat/labman/Appendix-B.htm)

Incompatible Chemicals

Chemical	**Keep Out of Contact With:**
Acetic Acid	Nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali Metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, the halogens
Ammonia, Anhydrous	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Bromine	Same as chlorine: ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Butyl lithium	Water
Carbon, activated	Calcium hypochlorite, all oxidizing agents

Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organic or combustible materials
Chromic Acid	Naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids in general
Chlorine	Same as bromine: ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids, organic or inorganic
Cyanides (Na, K)	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens, other oxidizing agents
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluoric acid	Ammonia, aqueous or anhydrous
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidizing gases
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitric Acid	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases
Oxalic acid	Silver, mercury
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, sulfuric acid, organics
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium permanganate	Glycerin, ethylene glycol, benzaldehyde, sulfuric acid
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds

Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (or compounds with similar light metals, such as sodium, lithium, etc.)

Appendix A-7

Ordering and Procurement of Chemicals

The achievement of safe handling, use, and disposal of hazardous substances begins with the persons who requisition such substances and those who approve their purchase orders. These persons must be aware of the potential hazards of the substances being ordered, know whether or not adequate facilities and trained personnel are available to handle such substances, and should ensure that a safe disposal route exists.

Before a new substance is received, information concerning its proper handling methods (including proper disposal procedures) shall be given to all those who will be working with it. It is the responsibility of the laboratory supervisor to ensure that the facilities are adequate and that those who will handle any material have received proper training and education to do so safely.

For most substances, Safety Data Sheets/Material Safety Data Sheets, which give physical property data and toxicological information, can be obtained by request to the vendor. However, the quality and depth of information on these sheets varies widely. These sheets shall be in the possession of the ordering department prior to ordering and before the chemicals are received on campus.

The US Department of Transportation (DOT) requires that shippers furnish and attach DOT prescribed labels on all shipment of hazardous substances. These labels indicate the nature of the hazard(s) of the substance(s) shipped and thus provide some indication to receiving personnel of the type of hazard received.

No container or cylinder should be accepted that does not have an identifying label. **Every effort should be made to ensure that this label remains on the container and legible.** For chemicals, it is desirable that this label correspond to ANSI Z129.1, which requires, at a minimum, the following components:

1. Identification of contents of container;
2. Signal word and summary description of any hazard(s);
3. Precautionary information - what to do to minimize hazard or prevent an accident from happening;
4. First aid in case of exposure;
5. Spill and cleanup procedures;
6. If appropriate, special instructions to physicians.

Appendix A-8

STORING CHEMICALS IN STOREROOMS AND STOCKROOMS

{The following was extracted and adapted from Prudent Practices For Handling Hazardous Chemicals in Laboratories (National Research Council, 1981)

There is a range of possibilities for storing chemical substances. The arrangements made will depend on the size of the facility, the quantities handled and the nature of the problems.

Often, the provision of adequate storage space is given little consideration in the design of laboratory buildings. Lack of sufficient storage space can create hazards due to overcrowding, storage of incompatible chemicals together, and poor housekeeping. Adequate, properly designed and ventilated storage facilities should be provided to ensure personnel safety and property protection.

In many instances, chemicals are delivered after receipt in the institution directly to the individual who initiated the order. If the facilities of the laboratory are appropriate for the kinds and quantities of materials used, this system may be eminently satisfactory.

However, experience has shown that it is usually necessary to maintain a reserve of supplies in excess of the amounts that can be kept safely in the laboratory. If the quantities are large or the volumes of the individual containers are such that repackaging is necessary, then a safe place is needed to store these containers and to perform these functions. Depending on needs, this could be a stockroom for the laboratory or a central storeroom for the particular facility.

Stored chemicals should be examined at periodic intervals (at least annually). At this time, those substances that have been kept beyond their appropriate shelf life or have deteriorated, have questionable labels, are leaking, have corroded caps, or have developed any other problem should be disposed of in a safe manner. A first-in, first out system of stock keeping should be used.

Shelved chemicals can walk, creep, and even tip over. Such chemicals can be prevented from falling off by placing retaining shock cords or similar restraining devices across the open face of the shelf or by raising the forward face of the shelf about one-quarter inch.

STOCKROOM DESIGN

Stockrooms are similar to central storerooms except that the quantities of materials involved are usually much smaller (the materials stored will be the inventory for a particular laboratory or group of laboratories) and such rooms are usually within or close to the areas served.

Stockrooms should not be used a preparation areas because of the possibility that an accident will occur and thereby unnecessarily contaminate a large quantity of materials. Preparation and repackaging should be performed in a separate area.

Stockrooms should be conveniently located and open during normal working hours so that laboratory workers need not store excessive quantities of chemicals in their laboratories. However, this does not imply that all laboratory workers should have unlimited access to the chemicals in the stockroom. Procedures must be established for the operation of any stockroom that place responsibility for its safety and inventory control in the hands of one person. If it is not feasible to have a full-time stockroom clerk, then one person who is readily available should be assigned that responsibility.

Stockrooms should be well ventilated. If storage of opened containers is permitted, extra local exhaust ventilation and the use of outside storage containers or spill trays are necessary.

FLAMMABLE LIQUIDS

Centralized storage of bulk quantities of flammable liquids provides the best method of controlling the associated fire hazard.

Because the most effective way to minimize the impact of a hazard is to isolate it, a storage and dispensing room for flammable liquids is best located in a special building separated form the main building. If this is not feasible, and the room must be located in a main building, the preferred location is a cutoff area on the at-grade level and having at least one exterior wall. [NOTE: Cutoff is a fire-protection term defined as "separated from other areas by fire-rated construction."] In any case, storage rooms for flammable liquids should not be placed on the roof, located on a below-grade level, an upper floor, or in the center of the building. All of these locations are undesirable because they are less accessible for fire fighting and potentially dangerous to the safety of the personnel in the building.

The walls, ceilings, and floors of an inside storage room for flammable liquids should be constructed of materials having at least a 2-hour fire resistance, and there should be self-closing Class B fire doors. All storage rooms should have adequate mechanical ventilation controlled by a switch outside the door and explosion-proof lighting and switches. Other potential sources of ignition, such as burning tobacco and lighted matches should be forbidden.

DRUM STORAGE

Fifty-five gallon drums are commonly used to ship flammable liquids but are not intended as long-time inside storage containers. It is not safe to dispense from sealed drums exactly as they are received. The bung should be removed and replaced by an approved pressure and vacuum relief vent to protect against internal pressure buildup in the event of fire or if the drum might be exposed to direct sunlight.

If possible, drums should be stored on metal racks placed such that the end bung openings are toward an aisle and the side bung openings are on top. The drums, as well as the racks, should be grounded with a minimum length of gage 10 wire. Because effective grounding requires metal-to-metal contact, all dirt, paint, and corrosion must be removed from the contact areas. Spring-type battery clamps and a minimally sized conductor (e.g., American wire gage 8 or 10) are satisfactory. It is also necessary to provide bonding to metal receiving containers to prevent accumulation of static electricity (which will discharge to the ground, creating a spark that could ignite the flammable vapors). Drip pans that have flame arrestors should be installed or placed under faucets.

Dispensing from drums is usually done by one of two methods. The first is gravity based through drum faucets that are self-closing and require constant hand pressure for operation. Faucets of plastic construction are not generally acceptable due to chemical action on the plastic materials.

The second, and safer, method is to use an approved hand-operated rotary transfer pump. Such pumps have metering options and permit immediate cutoff control to prevent overflow and spillage, can be reversed to siphon off excess liquid in case of overfilling, and can be equipped with drip returns so that any excess liquid can be returned to the drum.

TOXIC SUBSTANCES

Toxic substances should be segregated from other substances and stored in a well-defined or identified area that is cool, well-ventilated, and away from light, heat, acids, oxidizing agents, moisture, and such.

The storage of unopened containers of toxic substances normally presents no unusual requirements. However, because containers occasionally develop leaks or are broken, storerooms should be equipped with exhaust hoods or equivalent local ventilation devices in which containers of toxic substances can be handled.

Opened containers of toxic substances should be closed with tape or other sealant before being returned to the storeroom and should not be returned unless some type of local exhaust ventilation is available.

WATER-SENSITIVE CHEMICALS

Some chemicals react with water to evolve heat and flammable or explosive gases. For example, potassium and sodium metals and many metal hydrides react on contact with water to produce hydrogen, and these reactions evolve sufficient heat to ignite the hydrogen with explosive violence. Certain polymerization catalysts, such as aluminum alkyls, react and burn violently on contact with water.

Storage facilities for water-sensitive chemicals should be constructed to prevent their accidental contact with water. This is best accomplished by eliminating all sources of water in the storage area; for example, areas where large quantities of water sensitive chemicals are stored should not have automatic sprinkler systems. Storage facilities for such chemicals should be of fire-resistant construction, and other combustible materials should not be stored in the same area.

COMPRESSED GASES

Cylinders of compressed gases should be stored in well-ventilated, dry areas. Where practicable, storage rooms should be of fire-resistant construction and above ground. Cylinders may be stored out of doors, but some protection must be provided to prevent corrosion of the cylinder bottom and air circulation must not be restricted. All storage and use of compressed gases should be in compliance with OSHA regulations (29 CFR 1910.166-171).

Compressed gas cylinders should not be stored near sources of ignition nor where they might be exposed to corrosive chemicals or vapors. They should not be stored where heavy objects might strike or fall on them, such as near elevators, service corridors, and unprotected platform edges.

The cylinder storage area should be posted with the names of gases stored. Where gases of different types are stored at the same location, the cylinders would be grouped by type of gas (e.g., flammable, toxic, or corrosive). If possible, however, flammable gases should be store separately from other gases and provision should be made to protect them from fire. Full and empty cylinders should be stored in separate portions of the storage area, and the layout should be arranged so that older stock can be used first with minimum handling of other cylinders.

Cylinders and valves are usually equipped with various safety devices, including a fusible metal plug that melts at 70-95°C. Although most cylinders are designed for safe use up to a temperature of 50°C, they should not be placed where they can become overheated (e.g., near radiators, steam pipes, or boilers). Cylinder caps to protect the container withdrawal valve should be in place at all times during storage and movement to and from storage.

Cylinders should be stored in an upright position where they are unlikely to be knocked over, or they should be secured in an upright or horizontal position. Acetylene cylinders should always be stored valve end up to minimize the possibility of solvent discharge. Oxygen should be stored in an area that is at least 20 feet away from any flammable or combustible materials (especially oil and grease) or separated from them by a noncombustible barrier at least 5 feet high and having a fire resistance rating of at least 1/2 hour.

Cylinders are sometimes painted by the vendor to aid in the recognition of their contents and make separation of them during handling easier. However, this color coding is not a reliable method for identification of their contents; the stenciled or printed name on the cylinder is the only accepted method. If it is suspected that a stored cylinder is leaking, follow proper emergency procedure.

Appendix A-9

DISTRIBUTING CHEMICALS FROM STOCKROOMS TO LABORATORIES

{The following was extracted and adapted from Prudent Practices For Handling Hazardous Chemicals in Laboratories (National Research Council, 1981)

The method of transport of chemicals between stockrooms and laboratories must reflect the potential danger posed by the specific substance.

CHEMICALS

When chemicals are hand carried, they should be placed in an outside container or acid-carrying bucket to protect against breakage and spillage. When they are transported on a wheeled cart, the cart should be stable under the load and have wheels large enough to negotiate uneven surfaces (such as expansion joints and floor drain depressions) without tipping or stopping suddenly.

Provisions for the safe transport of small quantities of flammable liquids include:

a) the use of rugged pressure-resistant, non-venting containers
b) storage during transport in a well ventilated vehicle
c) elimination of potential ignition sources

CYLINDERS OF COMPRESSED GASES

The cylinders that contain compressed gases are primarily shipping containers and should not be subjected to rough handling or abuse. Such misuse can seriously weaken the cylinder and render it unfit for further use or transform it into a rocket having sufficient thrust to drive it through masonry walls. To protect the valve during transportation, the cover cap should be left screwed on hand tight until the cylinder is in place and ready for actual use. Cylinders should never be rolled or dragged. The preferred transport, even for short distances, is by suitable hand truck with the cylinder strapped in place. Only one cylinder should be handled at a time.

Handling and Transportation of Chemicals

(from https://ehs.okstate.edu/hazmat/labman/chap3c5.htm)

Many laboratory accidents occur through the simple operation of carrying chemicals from one place to another or transferring them from one container to another. The chemicals used in a laboratory are often corrosive, toxic, or flammable and any accident involving these has the potential for personal injury. Therefore, it is good practice to assume that all chemicals are potentially hazardous.

1. When large bottles of acids, solvents, or other liquids are transported within the laboratory without a cart, only one bottle should be carried at a time. The bottle should be carried with both hands, one on the neck of the bottle and the other underneath. Avoid the temptation to hook a finger through the glass ring on top of the bottle, allowing it to dangle while being transported. Never carry or attempt to pick up a bottle by the cap. A bottle transporter is the safest way to transport; it can also serve as secondary containment.

2. When transporting bottles within the laboratory, a wheeled cart may be used. Carts should be stable under load and have wheels large enough to negotiate uneven surfaces (such as expansion joints and floor drain depressions) without tipping or stopping suddenly. Do not place the bottles near the edge of the cart, nor should bottles touch other bottles or glassware during transport. Be cautious rolling the cart over door sills or other possible obstructions. When transporting on sidewalks and other paved outdoor surfaces, two people must be in attendance to prevent tipping the cart as it is moved over uneven terrain and changes in elevation.

NOTE: Incompatible chemicals should not be transported on the same cart. A list of incompatible chemicals is included in Appendix A-6.

3. Individuals transporting chemicals must ensure containers are properly labeled and know what to do in the event of a release or spill. Safety Data Sheets/Material Safety Data Sheets (MSDS) are a good source for this information and should accompany the materials being transported.

4. Wear appropriate Personal Protective Equipment (PPE). Minimum PPE includes safety glasses, lab coat or other appropriate lab attire, and closed-toe shoes. Hazardous chemicals must be attended at all times while being transported.

5. Freight-only elevators should be used, if possible, when transporting chemicals, to avoid exposure to persons on passenger elevators. If freight elevators are not available, use unoccupied passenger elevators. Special padded bottle transporter or rubber bottle carriers, pails, or carts should be used to prevent breakage by accidental striking against walls or floor, and to contain the material if breakage does occur. Materials that are unstable, explosive, or unusually hazardous due to size or toxicity (e.g., outdated peroxide formers such as THF, dry Picric Acid, or larger than 20 gallon containers of acutely hazardous materials) should not be moved. Contact Facilities Management for assistance.

6. Large quantities of concentrated mineral acids, e.g., sulfuric, nitric and hydrochloric acids, shall be kept in storage rooms, in cabinets for corrosive substances, or chemical transfer rooms. Bottles of concentrated acids must be carried from the aforementioned areas in an approved acid bottle carrier.

Organic solvents shall also be stored in specialized flammable storage areas. These solvents shall be carried from storage areas in special rubber carriers. Organic solvents can present fire hazards as well as inhalation hazards.

For information on transportation and storage of compressed gases see Appendix A- 14 "Handling of Compressed Gas."

Appendix A-10

STORING CHEMICALS IN LABORATORIES

{The following was extracted and adapted from Prudent Practices For Handling Hazardous Chemicals in Laboratories (National Research Council, 1981)

The amounts of toxic, flammable, unstable, or highly reactive materials that should be permitted in laboratories are an important concern. To arbitrarily restrict quantities may interfere with laboratory operations but, conversely, unrestricted quantities can result in the undesirable accumulation of such materials in the laboratory. It is, however, necessary to comply with any local statutory restrictions on allowable quantities.

Balancing the needs of the laboratory workers with the established requirements for safety is necessary. Decisions in this area will be affected by the level of competence of the workers, the level of safety features designed into the facility, the location of the laboratory, the nature of the chemical operations, and the accessibility of the stockroom. In general, all laboratories should have two exits (one may be an emergency exit) so that a fire at one exit will not block occupants' escape; doors that open outward are desirable.

GENERAL CONSIDERATIONS

Every chemical in the laboratory should have a definite storage place and should be returned to that location after each use.

The storage of chemicals on bench tops is undesirable; in such locations, they are unprotected from potential exposure to fire and are also more readily knocked over. **Storage in hoods is also inadvisable because this practice interferes with the air flow in the hood, clutters up the working space, and increases the amount of materials that could become involved in a fire.**

Storage trays or secondary containers should be used to minimize the distribution of material should a container break or leak.

Because most laboratory workers tend to store hazardous materials in the cabinet space under the hood, the provision of cabinets in this location is advisable. Just because there is storage space beneath a hood's counter top does not necessarily indicate that the space is vented by the hood. The use of ventilated cabinets also has the advantage that, because of proximity to the hood, the safe practice of making transfers of hazardous materials in the hood is encouraged.

Laboratory refrigerators are to be used for the storage of chemicals or laboratory supplies only; **food must not be place in them.** All containers placed in the refrigerator should be properly labeled (identification of contents and owner, date of acquisition or preparation, and nature of any potential hazard) and, if necessary, should be sealed to prevent escape of any corrosive vapors. Flammable liquids should not be stored in laboratory refrigerators unless the unit is an approved, explosion proof, or laboratory-safety type (See NFPA standard 45 and 56D).

The chemicals stored in the laboratory should be inventoried periodically, and unneeded items should be returned to the stockroom or storeroom. At the same time, containers that have illegible labels and chemicals that appear to have deteriorated should be disposed of.

On termination, transfer, graduation, or such of any laboratory personnel, those personnel and the laboratory supervisor (or someone acting as an agent of the department) should arrange for the removal or safe identification and storage of all hazardous materials those persons have on hand.

FLAMMABLE LIQUIDS

OSHA regulations for laboratory storage of flammable and combustible liquids are not based on fire prevention and protection principles but rather address the types and sizes of containers allowable [and would permit the storage of 60 gallon metal drums in laboratories of colleges and universities]. The NFPA Standard 45, however, has a quantity limit of storage per square footage of floor space which is dependent on the construction and fire protection afforded in the laboratory. This standard restricts instructional laboratories to half the quantities for industrial or graduate student laboratories. The NFPA Standard 30 addresses the amount that may be stored outside of an approved flammable liquid storage room or cabinet, but does not consider fire protection features available.

Whenever feasible, quantities of flammable liquids greater than 1 liter should be stored in metal containers. Portable approved safety cans are one of the safest methods of storing flammable liquids. These cans are available in a variety of sizes and materials. They have spring-loaded spout covers that can open to relieve internal pressure when subjected to a fire and will prevent leakage if tipped over. Some are equipped with a flame arrestor (usually a screen which many people mistake for a debris filter) in the spout that will prevent flame propagation into the can. If possible, flammable liquids received in large containers should be repackaged into safety cans for distribution to laboratories. Such cans must be properly labeled to identify their contents.

Small quantities of flammable liquids should be stored in ventilated storage cabinets made of 18 gage steel and having riveted and spot-welded seams. Such cabinets are of double-wall construction and have a 1.5 inch air space between the inner and outer walls. The door is 2 inches above the bottom of the cabinet, and the cabinet is liquid tight to this point. It is provided with vapor-venting provision and can be equipped with a sprinkler system. (Materials that react with water should not be stored in sprinkler equipped cabinets.) Some models have doors that close automatically in the event of fire.

If, for reasons of cost or space limitations, storage cabinets must be constructed of wood, they should be built in accordance with NFPA specifications.

In any case, the hazard of storage of flammable materials in wooden cabinets in existing laboratories can be decreased by the use of intumescent fire-retardant coatings or other means that provide effective fire insulation.

Other considerations in the storage of flammable liquids in the laboratory include ensuring that aisles and exits are not blocked in the event of fire; that accidental contact with strong oxidizing agents such as chromic acid, permanganates, chlorates, perchlorates, and peroxides is not possible; and that sources of ignition are excluded.

TOXIC SUBSTANCES

Chemicals known to be highly toxic, including those classified as carcinogens, should be stored in ventilated storage areas in unbreakable chemically resistant secondary containers.

Only minimum working quantities of toxic material should be present in the work area. Storage vessels containing such substances should carry a label such as the following: **CAUTION: HIGH CHRONIC TOXICITY** or **CANCER-SUSPECTED AGENT**

Storage areas for substances that have high acute or chronic toxicity should exhibit a sign warning of the hazard, have limited access, and be adequately ventilated. An inventory of these toxic materials should be maintained. For those chronically toxic materials designated as regulated carcinogens, this inventory is required by federal and state regulations. Adequate ventilation is of particular concern for hazardous materials that have a high vapor pressure (such as bromine, mercury, and mercaptans).

COMPRESSED GASES

Cylinders of compressed gases should be securely strapped or chained to a wall or bench top to prevent their being knocked over accidentally. When they are not in use, it is good practice to keep them capped. Care should be taken to keep them away from sources of heat or ignition.

Appendix A-11
HANDLING SPILLS

[For Mercury Spills, see Appendix A-12]

{The following was extracted and adapted from Prudent Practices For Handling Hazardous Chemicals in Laboratories (National Research Council, 1981)

Experience has shown that the accidental release of hazardous substances is a common enough occurrence to require preplanning for procedures that will minimize exposure of personnel and property. Such procedures may range from having available a sponge, mop and bucket to having an emergency spill-response team, complete with the appropriate protective apparel, safety equipment, and materials to contain, confine, dissipate, and clean up the spill.

The preplanning should include consideration of the following factors:

1. Potential location of the release (e.g., outdoors vs. indoors; in a laboratory, corridor, or storage area, on a table, in a hood, or on the floor)

2. The quantities of material that might be released and whether the substance is a piped material or a compressed gas.

3. Chemical and physical properties of the material (e.g., its physical state, vapor pressure, and air or water reactivity).

4. Hazardous properties of the material (its toxicity, corrosivity, and flammability)

5. The types of personal protective equipment that might be needed.

In any event, there should be supplies and equipment on hand to deal with the spill, consistent with the hazards and quantities of the spilled substance. These cleanup supplies should include neutralizing agents (such as sodium carbonate and sodium bisulfate) and adsorbents (such as vermiculite and sand). Paper towels and sponges may also be used as absorbent-type cleanup aids, although this should be done cautiously. For example, paper towels used to clean up a spilled oxidizer may later ignite, and appropriate gloves should be worn when wiping up highly toxic materials with paper towels. Also, when a spilled flammable solvent is absorbed in vermiculite or sand, the resultant solid is highly flammable and gives off flammable vapors and, thus, must be properly contained or removed to a safe place.

Commercial spill kits are available that have instructions, adsorbents, reactants, and protective equipment. These kits may be located strategically around work areas much as fire extinguishers are.

If a spill does occur, the following general procedures may be used but should be tailored to individual and situational needs (*for mercury spills, see Small-Scale Mercury Spill Response, Appendix A-12):

1. Attend to any persons who may have been contaminated.

2. Notify persons in the immediate area about the spill.

3. Evacuate all nonessential personnel from the spill area.

4. If the spilled material is flammable, turn off all ignition and heat sources.

5. Avoid breathing vapors of the spilled materials; if necessary, use a respirator (only if trained and tested in its use).

6. Leave on or establish exhaust ventilation if it is safe to do so.

7. Secure proper supplies to effect clean up.

8. During cleanup wear appropriate apparel.

9. Notify Facilities Management and your department and campus chemical hygiene officer.

10. Record the spill in the Spill Log form provided in each laboratory.

Handling of Spilled Liquids

1. Confine or contain the spill to a small area. Do not let it spread.

2. For small quantities of inorganic acids or bases, use a neutralizing agent or an absorbent mixture (e.g., soda ash or diatomaceous earth). For small quantities of other materials, absorb the spill with a nonreactive material (such as vermiculite, dry sand, or towels).

3. For larger amounts of inorganic acids and bases, flush with large amounts of water (provided that the water will not cause additional damage). Flooding is not recommended in storerooms where violent spattering may cause additional hazards or in areas where water-reactive chemicals may be present.

4. Mop up the spill, wringing out the mop in a sink or a pail equipped with rollers.

5. Carefully pick up and clean any cartons or bottles that have been splashed or immersed.

6. Vacuum the area with a vacuum cleaner approved for the material involved, remembering that the exhaust of a vacuum cleaner can create aerosols and, thus, should be vented to a hood or through a filter.

7. If the spilled material is extremely volatile, let it evaporate and be exhausted by the mechanical ventilation system (provided that the hood and associated mechanical system is spark-proof).

8. Dispose of residues according to safe disposal procedures.

Handling of Spilled Solids

Generally, sweep spilled solids of low toxicity into a dust pan and place them in a solid-waste container for disposal. Additional precautions such as the use of a vacuum cleaner equipped with a HEPA filter may be necessary when cleaning up spills of more highly toxic solids.

Handling of Leaking Compressed Gas Cylinders

Occasionally, a cylinder or one of its component parts develops a leak. Most such leaks occur at the top of the cylinder in areas such as the valve threads, safety device, valve stem, and valve outlet.

If a leak is suspected, do not use a flame for detection; rather a flammable-gas leak detector or soapy water or other suitable solution should be used. If the leak cannot be remedied by tightening a valve gland or a packing nut, emergency action procedures should be effected and the supplier should be notified. Laboratory workers should never attempt to repair a leak or the valve threads or safety device; rather, they should consult the supplier for instructions.

The following general procedures can be used for leaks of minimum size where the indicated action can be taken without serious exposure of personnel.

If it is necessary to move a leaking cylinder through populated portions of the building, place a plastic bag, rubber shroud, or similar device over the top and tape it (duct tape is preferred) to the cylinder to confine the leaking gas.

1. Flammable, inert, or oxidizing gases - Move the cylinder to an isolated area (away from combustible material if the gas is flammable or an oxidizing agent) and post signs that describe the hazards and state warnings.

2. Corrosive gases may increase the size of the leak as they are released and some corrosives are also oxidants or flammable - Move the cylinder to an isolated, well-ventilated area and use suitable means to direct the gas into an appropriate chemical neutralizer. Post signs that describe the hazards and state warnings.

3. Toxic gases - Follow the same procedure as for corrosive gases. Move the cylinder to an isolated, well ventilated area and use suitable means to direct the gas into an appropriate chemical neutralizer. Post signs that describe the hazards and state the warnings.

When the nature of the leaking gas or the size of the leak constitutes a more serious hazard, self-contained breathing apparatus (for those trained and tested in its use) or protective apparel, or both, may be required. Basic action for large or uncontrolled leaks may include any of the following steps:

1. evacuation of personnel

2. rescue of injured personnel by crew equipped with adequate personal protective apparel and breathing apparatus

3. fire fighting action (only if trained to do so)

4. emergency repair

5. decontamination

Appendix A-12

Small-Scale Mercury Spill Response Procedure

Liquid mercury can vaporize and is a health hazard. A spill of mercury is challenging to clean up because the beads of spilled mercury can scatter across surfaces and fall into cracks.

What to do if there is a small-scale mercury spill such as a broken thermometer:

1. If in a classroom or occupied room, have all students and personnel who did not come in contact and were not near the mercury spill leave the room immediately without walking near the contaminated area. If there is any chance of having tracked any of the spill or contacted any vapor, they should first remove and bag their shoes and leave inside the contained area, and then leave the room. If the shoes did not come in direct contact with the mercury, they can later be aired out.

2. Contact Facilities Management to request a clean-up (768-9576). They have a mercury spill kit and one is also available in the Chemical Storage Room Folsom 103B and Folsom Room 202. Facilities will contact the UMPI Emergency and Safety Coordinator, who will then contact the Department of Environmental Protection to report the spill.

3. Block off the contaminated area with caution tape and lock and bar further entry to the area. Consider shutting off air handlers to the area to minimize the spread of vapor and consider turning on an exhaust fan or chemical hood if present to remove the vapor.

<u>Initial clean-up</u>

Equipment needed: Mercury Spill Kit, water, paper towels, [eyedroppers, index cards], trisodium phosphate cleaning solution, plastic bags and a large overpack container.

1. Any person entering the area for clean-up should wear booties, coverall, protective glasses and gloves. Remove any jewelry. Keep a set of clean clothes outside of the area.
2. Identify what can be cleaned and what cannot. If items cannot be cleaned, such as those with fabric, place in plastic bag, tape shut and put in large waste can.
3. Carefully pick up broken glass and beads from the broken item onto a paper towel and gently surround with the paper towel and put in a zip-lock or thick type plastic bag. Do NOT use a broom or mop or vacuum cleaner at this point to clean up the mercury beads. An index card or scoop from the spill kit can be used to help direct the waste. A flashlight can be used to detect mercury beads and an eyedropper can be used to help pick up beads. All mercury beads, broken glass, paper towels and any other contaminated items should be placed in plastic bags, sealed and placed in a larger overpack container for hazardous waste that can be tightly shut.
4. Sprinkle absorption powder from a mercury spill kit onto the floor or bench area where the spill occurred and surrounding areas where it may have spread to. The powder binds to the mercury. Rub gently into cracks and other inaccessible areas. Dampen powder with wet paper towel, then

clean up area with wet paper towels. Collect all wet paper towels, put in plastic bags, seal and place in hazardous waste barrel. The activated sponge from the mercury spill kit can be used as well and capped when finished. Once all of the absorbent is cleaned up, a final scrub and wash with TSP (trisodium phosphate) can be performed. If a mop is used for this clean-up, the mop-head should be disposed of in the hazardous waste overpack container. All gloves should be taken off inside out and placed in the waste bags and overpack container.

5. Mercury indicator powder can be left overnight to identify any remaining mercury. If powder turns brown, mercury is present. Further clean-up is needed. Mercury Vapor Absorbent can be sprinkled into inaccessible areas to absorb vapors.
6. Call the Department of Environmental Protection to notify about the spill and clean-up, and to request a visit to identify if any remaining mercury vapor can be detected with their instruments.
7. All contaminated items and waste should be considered hazardous and should be disposed of by proper procedures for hazardous waste. They should be stored before pick-up in the Chemical Storage Area and logged into the hazardous waste manifest. UMPI uses Lab Pak, Inc. to pick-up and dispose of hazardous waste.

Resources:
Lab Safety Supply Mercury Spill Kit information
New York State Department of Health information page:
https://www.health.ny.gov/environmental/chemicals/hsees/mercury/cleaning_up_a_small_mercury_spill.htm

APPENDIX A-13

WORKING WITH HIGH AND LOW PRESSURES

{The following was extracted and adapted from Prudent Practices For Handling Hazardous Chemicals in Laboratories (National Research Council, 1981)

GLASS EQUIPMENT

The use of glassware for work at pressure extremes should be avoided whenever possible. Glass is a brittle material subject to unexpected failures due to factors such as mechanical impact and assembly and tightening stresses. Glass equipment, such as rotameters and liquid-level gages, that is incorporated in metallic pressure systems should be installed with shutoff valves at both ends to control the discharge of liquid or gaseous materials in the event of breakage.

Glass equipment in pressure or vacuum service should be provided with adequate shielding to protect users and others in the area from flying glass and the contents of the equipment. New or repaired glass equipment for pressure or vacuum work should be examined for flaws and strains under polarized light.

Corks, rubber stoppers, and rubber or plastic tubing should not be relied on as relief devices for protection of glassware against excess pressure; a liquid seal, Bunsen tube, or equivalent positive relief device should be used. When glass pipe is used, only proper metal fittings should be used.

PLASTIC EQUIPMENT

Except as noted below, the use of plastic equipment for pressure or vacuum work should be avoided unless no suitable substitute is available.

Tygon and similar plastic tubing have some limited applications in pressure work. These materials can be used for natural gas, hydrocarbons, and most aqueous solutions at room temperature and moderate pressure. Details of permissible operating conditions must be obtained from the manufacturer. Because of their very large coefficients of thermal expansion, some polymers have a tendency to expand a great deal on heating. Thus, if the valve or joint is tightened when the apparatus is cold, the plastic can entirely close an opening when the temperature increases. This problem can be a hazard in equipment subjected to very low temperatures or to alternating low and high temperatures.

PIPING, TUBING, AND FITTINGS

All-brass and stainless steel fittings should be used with copper or brass and steel or stainless steel tubings, respectively. It is very important that fittings of this type be installed correctly. It is not usually advisable to mix different types of fittings in the same apparatus assembly.

SEALED-TUBE REACTIONS

For any reaction run on a large scale (more than 10-20 g total weight of reactants) or at a maximum pressure in excess of 690 kPa (100 lbf/in^2), only procedures involving a suitable high-pressure autoclave should be used. However, it is sometimes convenient to run small-scale reactions at low pressures in a small sealed glass tube or in a thick-walled pressure bottle of the type used for catalytic hydrogenation. For any such reaction, the laboratory worker should be fully prepared for the not uncommon possibility that the sealed vessel will burst. Every precaution should be taken to avoid injury from flying glass or from corrosive or toxic reactants. Centrifuge bottles should be sealed with rubber stoppers clamped in place, wrapped with friction tape, surrounded by multiple layers of loose cloth toweling, and clamped behind a good safety shield. The preferred source of heat for such vessels is steam, because an explosion in the vicinity of an electrical heater could start a fire and an explosion in a liquid heating bath would distribute hot liquid around the area. Any reaction of this type should be labeled with signs that indicate the contents of the reaction vessel and the explosion hazard.

For reactions run in sealed tubes, similar precautions should be followed. The sealed glass tubes can be placed inside pieces of brass or iron pipe capped at one end with a pipe cap or, alternatively, in an autoclave containing some of the reaction solvent (to equalize the pressure inside and outside the glass tube). The tubes can be heated with steam or in a specially constructed, electrically heated "sealed-tube" furnace that is thermostatically controlled and located such that if an explosion should occur its force is directed into a safe area.

VACUUM WORK

In an evacuated system, the higher pressure is on the outside, rather than on the inside, so that a break causes an implosion rather than an explosion. The resulting hazards consist of flying glass, spattered chemicals, and possibly fire.

A moderate vacuum, such as 10 mm Hg, which can be achieved by a water aspirator, often seems safe compared with a high vacuum, such as 10^{-5} mm Hg. These numbers are deceptive, however, because the pressure differences between outside and inside are comparable ($760 - 10 = 750$ mm Hg in the first instance, compared with $760 - 10^{-5} = 760$ mm/Hg in the second instance). Therefore, *any* evacuated container must be regarded as an implosion hazard.

Vacuum distillation apparatus often provides some of its own protection in the form of heating mantles, column insulation, and the like; however, this is not sufficient because an implosion would scatter hot, flammable liquid. An explosion shield and a face mask should be used to protect the worker (Appendix A-2 and A-3).

Equipment at reduced pressure is especially prone to rapid changes in pressure. This can create large pressure differences within the apparatus that can push liquids into unwanted locations, sometimes with very undesirable consequences.

Water, solvents, or corrosive gases should not be allowed to be drawn into a building vacuum system. When the potential for such a problem exists, a water aspirator should be used as the vacuum source.

Mechanical vacuum pumps should be protected by using cold traps, and their exhausts should be vented to an exhaust hood or to the outside of the building. If solvents or corrosive substances are inadvertently drawn into the pump, the oil should be changed before any further use. The belts and pulleys on such pumps should be covered with guards.

GLASS VESSELS

Glass vessels at reduced pressure are capable of collapsing violently, either spontaneously (if cracked or in some other way weakened) or from an accidental blow. Therefore, pressure and vacuum operations should be conducted behind adequate shielding. It is advisable to check for flaws such as star cracks, scratches, or etching marks each time vacuum apparatus is used. Only round-bottomed or thick-walled, flat-bottomed flasks (e.g., Pyrex) specifically designed for operations at reduced pressure should be used a reaction vessels.

Repaired glassware is subject to thermal shock and should be avoided, whenever possible, for operations at reduced pressure.

DEWAR FLASKS

These flasks are capable of collapsing as a result of thermal shock or a very slight scratch caused by a stirring rod. They should be shielded, either by a layer of friction tape or by enclosure in a wooden or metal container, to reduce the hazard of flying glass in case of collapse.

DESICCATORS

Glass vacuum desiccators should be made of Pyrex or similar glass. They should be completely enclosed in a shield or wrapped with friction tape in a grid pattern that leaves the contents visible and at the same time guards against flying glass should the vessel collapse. Various plastic (e.g., polycarbonate) desiccators now on the market reduce the implosion hazard and may be preferable.

COLD TRAPS

Cold traps should be of sufficient size and low enough temperature to collect all condensable vapors present in a vacuum system and should be interposed between the system and the vacuum pump. They should be checked frequently to guard against their becoming plugged by the freezing of material collected in them.

The common practice of using acetone-dry ice as a coolant should be avoided. Isopropanol or ethanol work as well as acetone and are cheaper, less toxic, less flammable, and less prone to foam on addition of small particles of dry ice. Dry ice and liquefied gases used in refrigerant baths should always be open to the atmosphere; they should never be used in closed systems where they could develop uncontrolled and dangerously high pressures.

After completion of an operation in which a cold trap has been used, the system should be vented. This venting is important because volatile substances that have collected in the trap may vaporize when the coolant has evaporated and cause a pressure buildup that could blow the apparatus apart. In addition, the oil from some pumps can be sucked back into the system.

Extreme caution should be exercised in using liquid nitrogen as a coolant for a cold trap. If such a system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere, which, if the trap still contains organic material, will create a highly explosive mixture. Thus, a system that is connected to a liquid nitrogen trap should not be opened to the atmosphere until the trap has been removed. Also, if the system is closed after even a brief exposure to the atmosphere, some oxygen (or argon) may have already condensed. Then, when the liquid nitrogen bath is removed or when it evaporated, the condensed gases will vaporize with attendant pressure buildup and potential blowup.

ASSEMBLY OF VACUUM APPARATUS

Vacuum apparatus should be assembled so as to avoid strain. This requires that joints be assembled in a way that allows various sections of the apparatus to be moved if necessary without transmitting strain to the necks of the flasks. Heavy apparatus should be supported from below as well as by the neck.

Vacuum apparatus should be placed well into the bench or into the hood where it will not be easily struck by passers-by or the hood doors.

APPENDIX A-14

HANDLING OF COMPRESSED GASES

{The following was extracted and adapted from *<u>Prudent Practices For Handling Hazardous Chemicals in Laboratories</u>* *(National Research Council, 1981)*

Compressed gases present a unique hazard in that they have the potential for simultaneous exposure to both mechanical and chemical hazards (depending on the particular gas). If the gas is flammable, flash points lower than room temperature compounded by high rate of diffusion (instant permeation throughout the laboratory) present the danger of fire or explosion. Additional hazards can arise from the reactivity and toxicity of the gas, and asphyxiation can be caused by high concentrations of even "harmless" gases such as nitrogen. Finally, the large amount of potential energy resulting from compression of the gas makes a compressed gas cylinder a potential rocket or fragmentation bomb.

Thus, careful procedures are necessary for handling the various types of compressed gases, the cylinders that contain them, the regulators used to control their flow, and the piping used to confine them during flow.

CYLINDERS OF COMPRESSED GASES

The U.S Department of Transportation (DOT) which regulates the commercial transport of compressed gas cylinders has established codes that specify materials for construction, capacities, test procedures and service pressures of cylinders in which compressed gases are stored. All cylinders should indicate compliance with these standards.

Generally laboratory personnel should use prudent practices while using compressed gas cylinders. These practices include attention to proper identification, transportation and storage, handling and use, and the return of the empty cylinder.

IDENTIFICATION

The contents of any compressed gas cylinder should be clearly identified so as to be easily, quickly, and completely determined by any laboratory worker. Such identification should be stenciled or stamped on the cylinder itself or a label should be provided that cannot be removed from the cylinder. **No compressed gas cylinder should be accepted for use that does not legibly identify its contents by name.** ***Color coding is <u>not</u> a reliable means of identification; cylinder colors vary from supplier to supplier and labels on caps have no value as caps are interchangeable***. If the labeling on a cylinder becomes unclear or an attached tag is defaced, so that the contents cannot be identified, the cylinder should be marked "CONTENTS UNKNOWN" and returned directly to the manufacturer or supplier.

Empty compressed gas cylinders should be clearly marked as "empty" or "MT" and returned to storage area for pickup by the supplier.

All gas lines leading from a compressed gas supply should be clearly labeled so as to identify the gas, the laboratory served, and relevant emergency telephone numbers. The labels should be color coded to distinguish hazardous gases (such as flammable, toxic, or corrosive substances) (e.g., a yellow background and black letters) from safe (inert) gases (e.g., a green background and black letters). Signs should be conspicuously posted in areas in which flammable compressed gases are stored, identifying the substances and appropriate precautions (e.g., HYDROGEN - FLAMMABLE GAS - NO SMOKING - NO OPEN FLAMES).

HANDLING AND USE OF CYLINDERS

1. Compressed gas cylinders should be firmly secured at all times. A clamp and belt or chain are generally suitable for this purpose.

2. Pressure-relief devices protecting equipment that is attached to cylinders of flammable, toxic or otherwise hazardous gases should be vented to a safe place.

Standard cylinder-valve outlet connections have been devised by the Compressed Gas Association (CGA) to prevent the mixing of incompatible gases due to an interchange of connections. The outlet threads used vary in diameter; some are right-handed and some are left-handed. **In general, right-handed threads are used for nonfuel and water-pumped gases, and left-handed threads are used for fuel and oil-pumped gases.** Information on the standard equipment assemblies for uses with specific compressed gases are available from the supplier. To minimize undesirable connections that may result in a hazard, only CGA standard combinations of valves and fittings should be used in compressed gas installations; the assembly of miscellaneous parts (even of standard approved types) should be avoided. The threads on cylinder valves, regulators, and other fittings should be examined to ensure they correspond to one another and are undamaged.

3. Cylinders should be placed so that the cylinder valve is accessible at all times.

4. The main cylinder valve should be closed as soon as it is no longer necessary that it be open (i.e., it should never be left open when the equipment is unattended or not operating). This is necessary not only for safety when the cylinder is under pressure, but also to prevent the corrosion and contamination that would result from diffusion of air and moisture into the cylinder after it has been emptied.

Most cylinders are equipped with hand-wheel valves. Those that are not should have a spindle key on the valve spindle or stem while the cylinder is in service. **Only wrenches or other tools provided by the cylinder supplier should be used to open a valve.** In no case should pliers be used to open a cylinder valve. Some valves require washers, and this should be checked before the regulator is fitted.

5. Cylinder valves should be opened slowly

6. The valve on an unregulated cylinder should never be "cracked open."

7. There is never a necessity to open the main cylinder valve all the way; the resulting flow will be much greater than one would ever want. The safest and best practice is to open the main valve only to the extent necessary.

8.When opening the valve on a cylinder containing an irritating or toxic gas, the user should stand on the upwind side of the cylinder with the valve pointed downwind and should warn those working nearby in case of a possible leak.

STORAGE OF COMPRESSED GAS CYLINDERS

1. Cylinders of compressed gases should be stored in well-ventilated, dry areas. Where practicable, storage rooms should be of fire-resistant construction and above ground. Cylinders may be stored out of doors, but some protection must be provided to prevent corrosion of the cylinder bottom and air circulation must not be restricted.

2. Compressed gas cylinders should not be stored near sources of ignition nor where they might be exposed to corrosive chemicals or vapors.

3. They should not be stored where heavy objects might strike or fall on them, such as near elevators, service corridors, and unprotected platform edges.

4. The cylinder storage area should be posted with the names of the gases stored.

5. The cylinders should be grouped by type of gas (e.g., flammable, toxic, or corrosive). If possible, however, flammable gases should be stored separately from other gases and provision should be made to protect them from fire.

6. Full and empty cylinders should be stored in separate portions of the storage area, and the layout should be arranged so that older stock can be used first with minimum handling of cylinders.

Cylinders and valves are usually equipped with various safety devices, including a fusible metal plug that melts at 70-95°C. Although most cylinders are designed for safe use up to a temperature of 50°C, **they should not be placed where they can become overheated (e.g., near radiators, steam pipes, boilers).**

7. Cylinder caps to protect the container withdrawal valve should be in place at all times during storage and movement to and from storage.

8. Cylinders should be stored in storerooms in an upright position where they are secured or unlikely to be knocked over. When stored or placed in a laboratory, they should be securely strapped or chained to a wall or bench top to prevent their being knocked over accidently.

9. Acetylene cylinders should always remain upright to minimize the possibility of solvent discharge.

10. Oxygen cylinders should be stored in an area that is at least 20 feet away form any flammable or combustible materials (especially oil and grease) or separated from them by a

noncombustible barrier at least 5 feet high and having a fire resistance rating of at least 1/2 hour.

11. When cylinders are not in use, it is good practice to keep them capped.

FLAMMABLE GASES

Sparks and flames should be kept from the vicinity of cylinders of flammable gases. An open flame should never be used to detect leaks of flammable gases. Rather, soapy water should be used, except during freezing weather, when a 50% glycerine-water solution or its equivalent may be used. Connections to piping, regulators, and other appliances should always be kept tight to prevent leakage, and the hoses used should be kept in good condition.

Regulators, hoses, and other appliances used with cylinders of flammable gases should not be interchanged with similar equipment intended for use with other gases.

All cylinders containing flammable gases should be stored in a well-ventilated place. Reserve stocks of such cylinders should never be stored in the vicinity of cylinders containing oxygen.

SAFE HANDLING OF CERTAIN VENDOR SUPPLIED COMPRESSED GASES

ACETYLENE

Acetylene (C_2H_2) is special in several ways. First, it has the highest positive free energy of formation of any compound that most people ever encounter and is, hence, the most thermodynamically unstable common substance. Second, it has an exceedingly wide explosive range (from 2 to 80%). Furthermore, in addition to being explosive and shock sensitive, C_2H_2 can deflagrate in the absence of air to give (presumably) oligomers or polymers. Its stability is markedly enhanced by the presence of small amounts of other compounds, such as methane and, in fact, C_2H_2 from cylinders is rather safe to handle, because it is dissolved in acetone. For some uses, such as the preparation of acetylides, it is necessary to scrub the gas, thus removing the acetone. Such purified C_2H_2 is incomparably more dangerous than acetylene straight from the tank. Among other peculiarities of pure acetylene is the fact that its stability seems to be related to the diameter of the pipe used to transport it; it is actually less stable in wide bore piping. The handling and use of C_2H_2 under pressure is extremely hazardous. In the absence of compelling reasons to the contrary, all reactions and operations involving C_2H_2 should be run in a pressure laboratory that has the necessary facilities, as well as expertise and experience, for its safe handling.

Handling Procedures

Under no circumstances should C_2H_2 be used under pressure in unbarricaded equipment. In any case, the lowest pressure necessary for the desired work should always be used.

A pressure of 102 kPa (15 lbf/in^2) is generally accepted as presenting the maximum allowable hazard for supply line and regulator systems. However, even below this pressure, a serious hazard still exists, particularly in closed systems containing more than 1 liter of gaseous C_2H_2.

Equipment

Only UL-approved equipment should be used in acetylene service. Acetylene forms shock-sensitive and explosive compounds, including copper and silver acetylides. Alloys of these metals, including solders, should not be used for C_2H_2 service unless they have been specifically approved for this purpose. If it is known or suspected that acetylides have been formed, the campus Chemical Hygiene Officer should be consulted for safe methods of disposal.

Contaminated piping should not be used in C_2H_2 service. Acetylene reacts with explosive violence with oxidizing agents such as chlorine or oxygen. Explosive decomposition is known to be initiated by a variety of conditions, particularly elevated temperatures. When an acetylene cylinder is connected to a pressure reactor, a valving system should be used to prevent flashback into the supply system.

Only pressure regulators approved for C_2H_2 service should be used. These are fitted with a flame arrestor. All repairs or modifications of C_2H_2 regulators should be done by qualified personnel.

Used gages may be contaminated and should be put in C_2H_2 service only after thorough reconditioning and inspection by qualified personnel. Only gages that have Bourdon tubes constructed of stainless steel or an alloy containing less than 60% copper should be used for acetylene service. Ordinary gages usually contain brass and bronze parts that can lead to acetylide formation.

Cylinders of C_2H_2 must be protected from mechanical shock. The C_2H_2 is in solution, under pressure, in a porous, acetone-impregnated, monolithic filler and is safe to handle only in this state. Such cylinders must always be vertically positioned and have the valve end up when gas is withdrawn from them.

Purification

The purification of C_2H_2 at atmospheric pressure and room temperature is most efficiently done by scrubbing the gas through concentrated sulfuric acid and caustic traps. Activated alumina (F.1 grade), an all-purpose solid absorbent, is recommended where purification over a solid is desired. Activated carbon should be avoided because the heat of absorption may be sufficient to trigger thermal decomposition of the C_2H_2.

ANHYDROUS AMMONIA

A direct flame or steam jet must never be applied against a cylinder of ammonia (NH_3). If it becomes necessary to increase the pressure in a cylinder to promote more rapid discharge, the cylinder should be moved into a warm room. Extreme care should be exercised to prevent the temperature from rising above 50°C.

Only steel valves and fittings should be used on ammonia containers. Neither copper, silver, nor zinc nor their alloys should be permitted to come into contact with ammonia.

Respiratory protective equipment of a type approved by MSHA and NIOSH for anhydrous ammonia service should always be readily available in a place where this material is used and so located as to be easily reached in case of need. Persons expected to use this equipment must be trained and medically tested as required (see Appendix B-3). Proper protection should be afforded the eyes by the use of goggles or large-lens spectacles to eliminate the possibility of liquid NH_3 coming in contact with the eyes and causing injury.

Leaks may be detected with the aid of sulfur tapers or sensitive papers. Both of these items and instructions as to their use may be procured from the cylinder supplier.

CHLORINE

Toxicity

Humans can generally detect the odor of chlorine at about 0.3 ppm. Minimal irritation of the throat and nose are noticed at about 2.6 ppm and painful irritation at about 3.0 ppm and painful irritation at about 3.0 ppm; at a range of 2.6-41.0 ppm, a group of "trained industrial hygienists" noted "strong irritation." The subjective response to chlorine is less pronounced with prolonged exposure.

Experimentally determined responses to chlorine by humans are not very consistent. Throat irritation occurs at about 6.6-15 ppm. However, an exposure for medical purposes of a large number of humans to 5-7 ppm for 1 hour did not result in serious or long-term consequences. Exposure to about 17 ppm causes coughing, and levels as low as 10 ppm may cause lung edema.

Human exposure to 14-21 ppm for 30 minutes to 1 hour is regarded as dangerous and may, after a delay of 6 or more hours, result in death from anoxia due to serious pulmonary edema. For rats, the lethal concentration that kills 50% of the test population (LC_{50}) for 1 hour equals 293 ppm.

Chronic effects on humans from long-term low-level exposures have not been well documented. Animal exposures have indicated that prolonged exposure to approximately 1.7 ppm for 1 hour per day may cause deterioration in the nutritional state, blood alteration, and decreased resistance to disease.

Handling Procedures

Respiratory protective equipment of a type approved by MSHA and NIOSH for chlorine (Cl_2) service should always be readily available in places where this substance is used and so located as to be easily reached in case of need. Potential users of this equipment must be trained and medically tested as required. Proper protection should be afforded the eyes by use of goggles or large lens spectacles to eliminate the possibility of liquid CL_2 coming in contact with the eyes and causing injury. Chlorine should be used only by experienced or properly instructed persons.

The ACGIH's current TLV^R (1990) for chlorine is 0.5 ppm for an 8 hour time weighted average. Their Short Term Exposure Limit (STEL) is 1.0 ppm for 15 minutes. OSHA currently has a Permissible Exposure Limit (ceiling) of 1.0 ppm which may not be exceeded at any time.

Chlorine should be kept away from easily oxidized materials. Chlorine reacts readily with many organic chemicals, sometimes with explosive violence. Because of the high toxicity of chlorine, laboratory operations using it should be carried out in a certified hood and appropriate gloves should be worn.

CHLOROMETHANE

Toxicity

Chloromethane or methyl chloride (CH_3Cl) has a slight, not unpleasant odor, that is not irritating and may pass unnoticed unless a warning agent is added. Exposure to excessive concentrations of methyl chloride is indicated by symptoms similar to those of alcohol intoxication - drowsiness, mental confusion, nausea, and possibly vomiting.

Handling Procedures

Because methyl chloride may, under certain conditions, react with aluminum or magnesium to form materials that ignite or fume spontaneously in contact with air, contact with these metals should be avoided.

Suitable respiratory protective equipment should be available and kept in proper working order. Person with potential of using this equipment must be properly trained and medically tested prior to use.

FLUORINE

Toxicity

Fluorine (F_2) causes deep penetrating burns on contact with the body, an effect that may be delayed and progressive, as in the case of burns by hydrogen fluoride. The hazard of exposure to F_2 in the atmosphere is at least as great as that of chlorine.

Other properties

Fluorine reacts vigorously with most oxidizable substances at room temperature, frequently with immediate ignition, and with most metals at elevated temperatures. In addition, it reacts vigorously with silicon containing compounds and can thus support the continued combustion of glass, asbestos, and such. Fluorine forms explosive mixtures with water vapor, ammonia, hydrogen, and most organic vapors.

Handling Procedures

Because of the high activity of F_2, the area in the vicinity of a F_2 cylinder and its associated apparatus should be well ventilated and cleared of easily combustible material.

When a cylinder of F_2 is to be opened, the user should be protected by a suitable shield and the valve should be opened by remote control. Any apparatus that is to contain fluorine under pressure should be surrounded by a protective barrier. Fluorine cylinder valves are not adapted to fine adjustment, and the flow of F_2 from a cylinder should therefore be controlled by a needle valve located close to the cylinder and operated by remote control.

All equipment that may be in contact with fluorine should be completely dry. Protective measures against F_2 are not fully developed, and entry into zones contaminated with this substance should be avoided. Only positive pressure atmosphere supplying respiratory protective equipment is advised. Respirators may only be used by those persons who have been properly trained and tested. Gauntlet-type rubber gloves, rubber aprons, and face shields give only temporary protection against fluorine and , if brought into local contact with a F_2 leak, may inflame. A thorough flushing of F_2 lines with an inert gas should precede any opening of the lines for any reason.

The reaction of F_2 with some metals is slow and results in the formation of a protective metallic fluoride film. Brass, iron, aluminum, and copper, as well as certain of their alloys, react in this way at standard temperatures and pressures. Thus, these metals can be passivated by passing F_2 gas highly diluted with argon, neon, or nitrogen through tubing or over the surface with proper precautions and gradually increasing the concentration of F_2. As long as the protective coating is not cracked or dislodged to create a "hot spot," passivated apparatus is safe to use.

Once a fire has started that involves F_2 as an oxidizer, there is no effective way of stopping it other than shutting of the source of F_2. The area should be cleared and the fire allowed to burn itself out. No attempts should be made to extinguish the fire by using water or chemicals, as these act as additional fuel. Anyone in the vicinity of such a fire should wear impervious clothing and supplied-air or self-contained breathing apparatus.

HYDROGEN

Hydrogen (H_2) has an unusual and relatively unknown characteristic that, under certain conditions, presents a great hazard. Unlike other gases, the temperature of H_2 increases when the gas is expanded at a temperature higher than its inversion point (-80 C). This is known as the "inverse Joule-Thomson effect." It is well known that a cylinder of H_2 will sometimes emit a flash of fire when the cylinder valve is opened suddenly, permitting a rapid escape of gas. It is thought by some that the "inverse Joule-Thomson effect" plus the static charge generated by the escaping gas may cause its ignition.

Hydrogen has an extremely wide flammability range, the highest burning velocity of any gas and, although its ignition temperature is reasonably high, a very low ignition energy. Because no carbon is present, H_2 burns with a nonluminous flame that is often invisible in daylight. Hydrogen is nontoxic.

Handling Procedures

Hydrogen presents both combustion-explosion and fire hazards when released from containment. However, although its wide range of flammability and high burning rate accentuate these hazards, its low ignition energy, low heat of combustion on a volume basis, and nonluminous (low thermal-radiation level) flame are counteracting effects.

Because of its low ignition energy, when gaseous H_2 is released at high pressure, nominally rather small sources of heat (e.g., friction and static generation) often result in prompt ignition. Accordingly, H_2 is frequently thought of as a "self-igniting" under these circumstances. When H_2 is released at low pressures, however, self-ignition is unlikely. Hydrogen combustion explosions are characterized by very rapid pressure increases that are extremely difficult to vent effectively. Open-air or space explosions have occurred from large releases of gaseous H_2.

Because of its very low boiling point, contact between liquid H_2 and air can result in condensation of air and its oxygen and nitrogen components. A mixture of hydrogen and liquid oxygen is potentially explosive even though the quantities involved are likely to be small. Accidents from this source have been generally restricted to small containers of liquid H_2 that are handled open to the atmosphere and inside liquefaction equipment.

At ordinary temperatures, H_2 is very light, weighing only about 1/15 as much as air. The accordingly high diffusion rate makes it difficult for H_2 to accumulate in conventional structures and tends to reduce it combustion-explosion hazard.

Escaping gaseous hydrogen seldom presents a "no fire" emergency situation because it either is ignited promptly or rises in the atmosphere rapidly. Hydrogen gas vaporizing from the cryogenic liquid near its normal boiling point is slightly heavier than air at 20°C and, this causes it, together with the visible fog of condensed water vapor created, to spread along the ground for sizable distances (depending on the leak size and meteorological conditions). Because of the low gas density of vapors produced from vaporizing cryogenic liquid H_2, impounding or diked area are not required.

Ignitable mixtures can extend well beyond the visible cloud. Such escapes can be controlled by water spray. Contact between water and pooled H_2 should be avoided to prevent increased vaporization unless the vapor can be controlled.

Water should be applied to containers of H_2 exposed to fire, and the flow of gas should be stopped if possible. Because a H_2 flame is often invisible in daylight and produces such low levels of thermal radiation, such flames have actually been walked into. Thus, great care should be exercised when approaching a H_2 fire.

NITROGEN DIOXIDE

Toxicity

Nitrogen dioxide (NO_2) is classed as a primary irritant, acting primarily on the lungs and to a lesser extent on the upper respiratory tract. It is certainly one of the most insidious of gases. The inflammation of the lungs may cause only slight pain, but the edema that results may easily cause death. One hundred ppm of NO_2 in air is a dangerous concentration for even a short exposure, and 200 ppm may be fatal in a short time. Nitrogen dioxide gas is reddish brown, has an irritating odor that must be avoided.

Handling Procedures

Nitrogen dioxide is a deadly poison, and no one should work with a cylinder of this substance unless they are fully familiar with its handling and its toxic effect. Ventilation is extremely important, and respiratory protective equipment should always be available. Persons expected to use respiratory protective equipment must be properly trained and tested as required. Only stainless steel fittings should be used.

OXYGEN

Oils, greases, and other readily combustible substances should never come in contact with oxygen cylinders, valves, regulators, gages, and fittings. Oil and oxygen (O_2) may combine with explosive violence. Therefore, valves, regulators, gages, and fittings used in O_2 service must not be lubricated with oil or any other combustible substance. Oxygen cylinders or apparatus should not be handled with oily hands or gloves.

Oxygen regulators, hoses, and other appliances should not be interchanged with similar equipment intended for use with other gases. Cylinders of O_2 should not be stored near flammable materials, especially oils, greases, or any substance likely to cause or accelerate fire. Oxygen is not flammable, but supports combustion. Once a pure-oxygen fire begins, almost anything, including metal, will burn.

SULFUR DIOXIDE

Respiratory protective equipment of a type approved by MSHA and NIOSH for sulfur dioxide service should always be readily available in a place where this substance is used and so located as to be easily reached in case of need. Persons expected to use this equipment must be properly trained and tested as required. When liquid sulfur dioxide is used, the eyes should be protected by the use of goggles or large-lens spectacles.

Leaks of sulfur dioxide may be detected by passing a rag dampened with aqueous ammonia over the suspected valve or fitting. White fumes indicate escaping sulfur dioxide gas.

Appendix B: Infectious agents and potentially biohazardous waste.

Work performed at the University of Maine at Presque Isle will follow the guidelines of the Biosafety Levels established by the Center for Disease Control. See http://www.cdc.gov/biosafety/publications/bmbl5/index.htm

Biohazard waste generated in laboratories will either be autoclaved or removed by a biohazard waste disposal company. Storage bins and red autoclavable bags will be provided for such waste storage.

Appendix D

USE AND TYPES OF LABORATORY HOODS

The following is extracted and adapted from *Prudent Practices for Handling Hazardous Chemicals in Laboratories* *(National Research Council, 1981)*

USE OF LABORATORY HOODS

Although many laboratory workers regard hoods strictly as local ventilation devices to be used to prevent toxic, offensive, or flammable vapors from entering the general laboratory atmosphere, hoods offer two other significant types of protection. Placing a reacting chemical system within a hood, especially with the hood sash closed, also places a physical barrier between the workers in the laboratory and the chemical reaction. This barrier can afford the laboratory workers significant protection from hazards such as chemical splashes or sprays, fires, and minor explosions. Furthermore, the hood can provide and effective containment device for accidental spills of chemicals. In a laboratory where workers spend most of their time working with chemicals, there should be at least one hood for each two workers, and the hoods should be large enough to provide each worker with at least 2.5 linear feet of working space at the face. The optimum arrangement is to provide each laboratory worker with a separate hood. In circumstances where this amount of hood space cannot be provided, there should be reasonable provisions for other types of local ventilation and special care should be exercised in monitoring and restricting the use of hazardous substances.

The following factors should be remembered in the daily use of hoods:

1. Hoods should be considered as backup safety devices that can contain and exhaust toxic, offensive, or flammable materials when the design of an experiment fails and vapors or dusts escape from the apparatus being used.

2. Hoods should not be regarded as means for disposing of chemicals. Thus, apparatus used in hoods should be fitted with condensers, traps, or scrubbers to contain and collect waste solvents or toxic vapors or dusts. Highly toxic or offensive vapors should always be scrubbed or adsorbed before the exit gases are released into the hood exhaust system.

3. Ensure the area inside the hood is adequately illuminated

4. Use only hoods that have been certified for use by the University of Maine System's laboratory hood testing program. Hoods should be evaluated before use to ensure they are exhausting properly. This may be accomplished with a continuous monitoring device as simple as a paper streamer. If inadequate hood performance is suspected, it should be established that the hood is performing adequately before being used. (Contact your campus Chemical Hygiene Officer or Department of Facilities Management for further assistance).

5. Except when adjustments of apparatus within the hood are being made, the hood should be kept closed: vertical sashes down and horizontal sashes closed. Keeping the face opening of the hood small improves the overall performance of the hood.

6. The airflow pattern, and thus the performance of a hood, depends on such factors as placement of equipment in the hood, room drafts from open doors or windows, persons walking by, or even the presence of the user in front of the hood. Work at least 6 inches inside the hood

(from sash line). This will help prevent vapor leakage at the face opening. Also avoid rapid movement when working in and around an operating hood.

7. Hoods are not intended primarily for storage of chemicals. Materials stored in them should be kept to a minimum. Stored chemicals should not block vents or alter airflow patterns. Whenever practical, chemicals should be moved from hoods to vented cabinets for storage.

8. Solid objects and materials (such as paper) should not be permitted to enter the exhaust ducts of hoods as they can lodge in the ducts or fans and adversely affect their operation. Keep hoods clear of clutter.

9. Large laboratory equipment placed in the hood should be elevated at least two inches to improve airflow around the object.

10. An emergency plan should always be prepared for the event of ventilation failure (power failure, for example) or other unexpected occurrence such as fire or explosion in the hood.

11. If laboratory workers are certain that adequate general laboratory ventilation will be maintained when hoods are not running, hoods not in use should be turned off to conserve energy. If any doubt exists, however, or if toxic substances are being stored in the hood, the hood should be left on. Energy can also be conserved by the use of variable-volume hoods that modulate exhaust flow with sash position.

TYPES OF LABORATORY BENCH HOODS

Conventional or Standard

All air enters through the hood opening as defined by the bottom of the sash, the sides of the hood and the work surface.

By-pass

As the sash is closed some of the air enters through a bypass grille instead of through the face opening. This keeps air velocities across the work surface relatively consistent (100-300 lfpm). The bypass grille is usually located directly above the sash.

Auxiliary Air

In this type of hood some of the air being drawn into the face opening is supplied directly to the hood via a duct. The delivery duct is usually located just above the bypass grille and extends out 1-2 feet.

Radioactive

Any of the above listed hoods may be used for radioactive materials provided the interior work surfaces are impervious (usually stainless steel). Some types of radioactive material also require a filter at the hood outlet and surveillance by a qualified person.

Perchloric Acid

Any of the above hoods can also be used for perchloric acid provided the hood has a water wash down system.

Glove Box

This is a complete enclosure whose only access is through a side pass through chamber or the attached gloves in front. The box itself is usually kept a negative pressure of approximately 0.5" H_2O.

Biological Safety Cabinet

This type of hood is used for biological materials. It is <u>not</u> designed for use with hazardous chemicals. Only small quantities of non-volatile chemicals should be used in these hoods. If your laboratory has this type of hood, please find standard operating procedures that should be included in this laboratory safety plan.

USE A HOOD ONLY FOR THE FUNCTION FOR WHICH THE HOOD WAS DESIGNED.

Appendix I: Hazardous Waste Disposal Program

HAZARDOUS WASTE DISPOSAL PROGRAM

PROCEDURES FOR DISPOSING OF CHEMICALS IN LABORATORIES

Proper disposal of the substances they use is an important responsibility of all laboratory workers. Arrangements for disposal may vary from laboratory to laboratory, depending on the facilities and the types of substances used, but the basic principle is that substances must be disposed of in ways that avoid harm to people and the environment. Wastes should be transferred in a form that is safe and acceptable to the people involved in disposal operations. Considering the future fate of the waste substance is very important.

Generally hazardous waste will be placed in Folsom 103B in the cabinet designated for Hazardous waste, or in a designated temporary storage area in each laboratory. Materials in the temporary areas will be picked up by the Chemical Hygiene Officer, taken for storage in Folsom 103B, and entered into a hazardous waste manifest awaiting pick-up by a hazardous waste transfer company (e.g. Lab-Pak, Inc).

All laboratory workers and students collecting hazardous materials must follow these instructions:

The waste must be in a closed container and marked with the following information:

- Labeled *hazardous waste* (stickers are available in each laboratory)
- Hazardous material(s) enclosed in the container- chemicals [concentrations when known]
- Date
- Initials

Please inform the Chemical Hygiene Officer of any hazardous waste materials being stored in your laboratory so that they can be picked up and transported to the storage area awaiting transfer.

GENERAL CONSIDERATIONS

The plan for safe disposal of the substances used is as much a part of the plan for the experiment as is the acquisition of materials, the experimental procedures, and the isolation or storage. If an experiment involves new types of disposal problems, the laboratory worker should discuss the disposal plan with the laboratory supervisor (or department head) and, if necessary the safety coordinator or hazardous waste coordinator for your campus.

If practical, very hazardous substances should be converted to less hazardous substances in the laboratory rather than being placed directly in containers. For example, strong carcinogens should be oxidized in solution in the laboratory before disposal, and highly reactive substances, such as metallic sodium and peroxides, should be converted to less reactive substances. Reactions may be moderated by dilution, cooling, or the slow addition of a neutralizing agent. For water-miscible materials, pouring the reaction mixture onto a bed of ice can often be a way to cool and dilute it simultaneously.

All persons using chemicals in the laboratory should be generally aware of the toxic properties of the substance(s) used, including consideration of the toxic properties of possible reaction products. If the toxic properties of possible products are not known, the products should be treated with respect and the disposal method should take account of the uncertain hazards. Some products may be disposed of as an integral part of the experiment (e.g., by using a scrubber for a gaseous product).

The cleanup of a laboratory that has been damaged by fire may present special hazards, e.g., the presence of toxic chemicals in the atmosphere and work environment, and may require special precautions.

The disposal of chemicals from instructional laboratories is a special problem because the students in such laboratories are inexperienced, the quantities of wastes may be relatively large, and the facilities may not be optimum. Education of students about how to handle chemicals and dispose of them safely is an integral part of their laboratory training.

DISPOSAL TO THE SEWER SYSTEM

Sewer systems operate in various ways, and some of them may be harmed or may present hazards for people and the environment when some chemicals are added directly to them. Generally, there are local regulations about what may be poured down the drain. The laboratory supervisor should know the local regulations and communicate this information to the laboratory workers so that they can conform to the regulations. All laboratory workers should know and respect these regulations. For sewer systems that discharge into waterways, federal regulations limit the disposal of certain toxic chemicals. In general, the following rules regarding disposal into a sewer system should be followed:

1. Only water-soluble substances should be disposed of in the laboratory sink. Solutions of flammable solvents (i.e., alcohols) must be sufficiently dilute that they do not pose a fire hazard.

2. Strong acids and bases should be diluted to the pH 4-10 range before they are poured in the sewer system. Acids and alkalis should not be poured in the sewer drain at a rate exceeding the equivalent of 50 ml of concentrated substance per minute (with water).

3. Highly toxic, malodorous, or lachrymatory chemicals should not be disposed of down the drain. Laboratory drains are generally interconnected; a substance that goes down one sink may well come up as a vapor in another. Sinks are usually communal property, and there is a very real hazard of chemicals from two sources contacting one another; the sulfide poured into one drain may contact the acid poured into another, with unpleasant consequences for all in the building. Some simple reactions can even cause explosions (e.g., ammonia plus iodine, silver nitrate plus ethanol, or picric acid plus lead salts).

4. Heavy metal compounds should never be disposed of in the sink. They may pose a hazard for the sewer system or someone else's water supply.

DISPOSAL OF SOLID CHEMICAL WASTES

Your campus should have procedures for collecting solid chemical wastes from the laboratories and arranging for disposal by the proper organizations. These procedures will be placed in this section once they are formalized. They should include a clear understanding as to who is in charge and what the responsibilities of the laboratory workers are with respect to the identification of hazards that may be encountered in handling, transporting, and disposing of the solid waste. The people picking up such material should be aware of the hazards and know what to do in case of a spill during transportation.

The solid chemical wastes of a laboratory should be placed in containers provided for that purpose. When bottles are used, they should be placed in buckets. Ensuring that all wastes are adequately labeled is very important. The laboratory worker should be aware of the hazards that may be involved in disposing of particular solid chemical wastes and the importance of segregating incompatible materials.

DISPOSAL OF LIQUID CHEMICAL WASTES

Similar to the requirements for solid chemical wastes, your campus should have a procedure for collecting liquid chemical wastes from the laboratories and arranging for their disposal by the proper organizations. Suitable containers should be provided, and the laboratory workers should understand what may, or may not, be placed in these containers and which materials require special labeling.

Waste solvents that are free of solids and corrosive or reactive substances may be collected in a common bottle or can, which is taken away when full. If this system is used, it is essential to consider exactly what mixtures will go into the can and whether the substances involved are compatible (this may include waste from the neighboring laboratory). Segregation into two or three types of waste is often useful (e.g., chlorinated solvents, hydrocarbons), as is the use of completely separate bottles for waste that poses special difficulties. In particular, because chlorinated solvents for hydrogen chloride on combustion, they often must be segregated from materials destined for incineration as their burning will violate local air pollution ordinances. Generally speaking, separated and well-defined waste is easier to dispose of and, if an outside contractor is used, less expensive. All wastes posing hazards should be so labeled.

Some solvents (such as ether and secondary alcohols) form explosive peroxides on standing. Some reactions can cause explosions directly (e.g., acetone plus chloroform in the presence of a base). Others, such as acid-base interactions, can generate sufficient heat to vaporize or ignite flammable materials such as carbon disulfide. The addition of hot materials can cause the buildup of pressure in a tightly closed solvent container, with the potential for compressive ignition. The acid formed when halogenated solvents are left moist can corrode cans, as can any dissolved corrosive in a discarded mixture.

When large quantities of a solvent are involved, consideration should be given to recycling rather that disposal. This operation also involves some potential hazard and expense, but these limitations may be less severe than those for disposal, especially as disposal costs are expensive and are increasing.

DISPOSAL OF ESPECIALLY HAZARDOUS WASTES

This class of chemical wastes includes very toxic substances, strong carcinogens, mutagens, nerve gases, explosives, and substances in tanks and other sealed containers. The laboratory worker has the responsibility to ensure that proper arrangements for disposal of these materials are made. Wherever possible, chemical reaction in the laboratory to produce less hazardous substances should be undertaken. For the case of those chemicals regulated as carcinogens, EPA disposal rules must be followed.

A spill of one of these substances can be an especially serious hazard. Personnel working with such substances should have contingency plans, equipment, and materials available for coping with potential accidents (see Appendix A-11 and A-12).

SPILLS (Also found as Appendix A-11)

Experience has shown that the accidental release of hazardous substances is a common enough occurrence to require preplanning for procedures that will minimize exposure of personnel and property. Such procedures may range from having available a sponge mop and bucket to having an emergency spill-response team, complete with the appropriate protective apparel, safety equipment, and materials to contain, confine, dissipate, and clean up the spill.

The preplanning should include consideration of the following factors:

1. Potential location of the release (e.g., outdoors vs. indoors; in a laboratory, corridor, or storage area, on a table, in a hood, or on the floor).
2. The quantities of material that might be released and whether the substance is a piped material or a compressed gas.
3. Chemical and physical properties of the material (e.g., its physical state, vapor pressure, and air or water reactivity).
4. Hazardous properties of the material (its toxicity, corrosivity, and flammability)
5. The types of personal protective equipment that might be needed.

In any event, there should be supplies and equipment on hand to deal with the spill, consistent with the hazards and quantities of the spilled substance. These cleanup supplies should include neutralizing agents (such as sodium carbonate and sodium bisulfate) and adsorbents (such as vermiculite and sand). Paper towels and sponges may also be used as absorbent-type cleanup aids, although this should be done cautiously. For example, paper towels used to clean up a spilled oxidizer may later ignite, and appropriate gloves should be worn when wiping up highly toxic materials with paper towels. Also, when a spilled flammable solvent is absorbed in vermiculite or sand, the resultant solid is highly flammable and gives off flammable vapors and, thus, must be properly contained or removed to a safe place.

Commercial spill kits are available that have instructions, adsorbents, reactants, and protective equipment. These kits may be located strategically around work areas much as fire extinguishers are.

If a spill does occur, the following general procedures may be used but should be tailored to individual needs (**if mercury- **see Appendix A-12 Small-Scale Mercury Response**, below):

1. Attend to any persons who may have been contaminated.
2. Notify persons in the immediate area about the spill.
3. Evacuate all nonessential personnel from the spill area.
4. If the spilled material is flammable, turn off all ignition and heat sources.
5. Avoid breathing vapors of the spilled materials; if necessary, use a respirator (only if you have been trained and tested in its use).
6. Leave on or establish exhaust ventilation if it is safe to do so.
7. Secure proper supplies to effect clean up.
8. During cleanup wear appropriate apparel.
9. Notify Facilities Management, your department and the campus chemical hygiene officer.
10. Log the spill in the Spill Log provided in each laboratory.

Handling of Spilled Liquids

1. Confine or contain the spill to a small area. Do not let it spread.
2. For small quantities of inorganic acids or bases, use a neutralizing agent or an absorbent mixture (e.g., soda ash or diatomaceous earth). For small quantities of other materials, absorb the spill with a non-reactive material (such as vermiculite, dry sand, or towels.

3. For larger amounts of inorganic acids and bases, flush with large amounts of water (provided that the water will not cause additional damage). Flooding is not recommended in storerooms where violent spattering may cause additional hazards or in areas where water-reactive chemicals may be present.

4. Mop up the spill, wringing out the mop in a sink or a pail equipped with rollers.

5. Carefully pick up and clean any cartons or bottles that have been splashed or immersed.

6. Vacuum the area with a vacuum cleaner approved for the material involved, remembering that the exhaust of a vacuum cleaner can create aerosols and, thus, should be vented to a hood or through a filter.

7. If the spilled material is extremely volatile, let it evaporate and be exhausted by the mechanical ventilation system (provided that the hood and associated mechanical system is spark-proof).

8. Dispose of residues according to safe disposal procedures.

9. Log the spill in the Spill Log provided in each laboratory.

Handling of Spilled Solids

Generally, sweep spilled solids of low toxicity into a dust pan and place them in a solid-waste container for disposal. Additional precautions such as the use of a vacuum cleaner equipped with a HEPA filter may be necessary when cleaning up spills of more highly toxic solids.

Handling of Leaking Compressed Gas Cylinders

Occasionally, a cylinder or one of its component parts develops a leak. Most such leaks occur at the top of the cylinder in areas such as the valve threads, safety device, valve stem, and valve outlet.

If a leak is suspected, do not use a flame for detection; rather a flammable-gas leak detector or soapy water or other suitable solution should be used. If the leak cannot be remedied by tightening a valve gland or a packing nut, emergency action procedures should be effected and the supplier should be notified. Laboratory workers should never attempt to repair a leak in the valve threads or safety device; rather, they should consult the supplier for instructions.

The following general procedures can be used for leaks of minimum size where the indicated action can be taken without serious exposure of personnel.

If it is necessary to move a leaking cylinder through populated portions of the building, place a plastic bag, rubber shroud, or similar device over the top and tape it (duct tape is preferred) to the cylinder to confine the leaking gas.

1. Flammable, inert, or oxidizing gases - Move the cylinder to an isolated area (away from combustible material if the gas is flammable or an oxidizing agent) and post signs that describe the hazards and state warnings.

2. Corrosive gases may increase the size of the leak as they are released and some corrosives are also oxidants or flammable - Move the cylinder to an isolated, well-ventilated area and use suitable means to direct the gas into an appropriate chemical neutralizer. Post signs that describe the hazards and state warnings.

3. Toxic gases - Follow the same procedure as for corrosive gases. Move the cylinder to an isolated, well ventilated area and use suitable means to direct the gas into an appropriate chemical neutralizer. Post signs that describe the hazards and state the warnings.

When the nature of the leaking gas or the size of the leak constitutes a more serious hazard, self-contained breathing apparatus (for those trained and tested in its use) or protective apparel, or both, may be required. Basic action for large or uncontrolled leaks may include any of the following steps:

1. evacuation of personnel

2. rescue of injured personnel by crew equipped with adequate personal protective apparel and breathing apparatus

3. fire fighting action (only if trained to do so)

4. emergency repair

5. decontamination

Small-Scale Mercury Spill Response Procedure (also found as Appendix A-12)

Liquid mercury can vaporize and is a health hazard. A spill of mercury is challenging to clean up because the beads of spilled mercury can scatter across surfaces and fall into cracks.

What to do if there is a small-scale mercury spill such as a broken thermometer:

1. If in a classroom or occupied room, have all students and personnel who did not come in contact and were not near the mercury spill leave the room immediately without walking near the contaminated area. If there is any chance of having tracked any of the spill or contacted any vapor, they should first remove and bag their shoes and leave inside the contained area, and then leave the room. If the shoes did not come in direct contact with the mercury, they can later be aired out.

2. Contact Facilities Management to request a clean-up (768-9576). They have a mercury spill kit and one is also available in the Chemical Storage Room Folsom 103B and Folsom Room 202. Facilities will contact the UMPI Emergency and Safety Coordinator, who will then contact the Department of Environmental Protection to report the spill.

3. Block off the contaminated area with caution tape and lock and bar further entry to the area. Consider shutting off air handlers to the area to minimize the spread of vapor and consider turning on an exhaust fan or chemical hood if present to remove the vapor.

Initial clean-up

Equipment needed: Mercury Spill Kit, water, paper towels, [eyedroppers, index cards], trisodium phosphate cleaning solution, plastic bags and a large overpack container.

1. Any person entering the area for clean-up should wear booties, coverall, protective glasses and gloves. Remove any jewelry. Keep a set of clean clothes outside of the area.
2. Identify what can be cleaned and what cannot. If items cannot be cleaned, such as those with fabric, place in plastic bag, tape shut and put in large waste can.
3. Carefully pick up broken glass and beads from the broken item onto a paper towel and gently surround with the paper towel and put in a zip-lock or thick type plastic bag. Do NOT use a broom or mop or vacuum cleaner at this point to clean up the mercury beads. An index card or scoop from the spill kit can be used to help direct the waste. A flashlight can be used to detect mercury beads and an eyedropper can be used to help pick up beads. All mercury beads, broken glass, paper towels and any other contaminated items should be placed in plastic bags, sealed and placed in a larger overpack container for hazardous waste that can be tightly shut.
4. Sprinkle absorption powder from a mercury spill kit onto the floor or bench area where the spill occurred and surrounding areas where it may have spread to. The powder binds to the mercury. Rub gently into cracks and other inaccessible areas. Dampen powder with wet paper towel, then clean up area with wet paper towels. Collect all wet paper towels, put in plastic bags, seal and place in hazardous waste barrel. The activated sponge from the mercury spill kit can be used as well and capped when finished. Once all of the absorbent is cleaned up, a final scrub and wash with TSP (trisodium phosphate) can be performed. If a mop is used for this clean-up, the mop-head should be disposed of in the hazardous waste overpack container. All gloves should be taken off inside out and placed in the waste bags and overpack container.
5. Mercury indicator powder can be left overnight to identify any remaining mercury. If powder turns brown, mercury is present. Further clean-up is needed. Mercury Vapor Absorbent can be sprinkled into inaccessible areas to absorb vapors.
6. Call the Department of Environmental Protection to notify about the spill and clean-up, and to request a visit to identify if any remaining mercury vapor can be detected with their instruments.
7. All contaminated items and waste should be considered hazardous and should be disposed of by proper procedures for hazardous waste. They should be stored before pick-up in the Chemical

Storage Area and logged into the hazardous waste manifest. UMPI uses Lab Pak, Inc. to pick-up and dispose of hazardous waste.

Resources:

Lab Safety Supply Mercury Spill Kit information

New York State Department of Health information page:
https://www.health.ny.gov/environmental/chemicals/hsees/mercury/cleaning_up_a_small_mercury_spill.htm

University of Maine at Presque Isle: Chemical Hygiene Plan

Table of Contents: Additional Appendices

APPENDIX E

TESTING PROCEDURES FOR CERTIFICATION OF LABORATORY FUME HOODS

The following procedures are to be used at least annually or following new laboratory fume hood installation, changes or repairs on the hood system, or on request by the user or facilities management to certify each hood for use**.**

STEP 1: VISUAL INSPECTION

1. Each laboratory hood shall be visually inspected to ensure:

a) Containment (including sash, table top, walls, and ceiling) and ductwork is free of deterioration or damage.

b) All electrical switches that operate the hood or systems within the hood are labeled and functioning properly.

c) Sash moves without restriction and may be set at any position without moving by itself.

d) Air flow indicators or alarms (if applicable) are in good working order and show proper indication.

e) Contents of the hood are in a neat, uncluttered condition.

STEP 2: FACE VELOCITY TESTING

1. Lift sash to fully open position.

2. Measure area of opening.

3. Activate unit.

4. Using a thermoaneometer, velometer, or venomotor, measure the air flow in the center of the hood at the face of the opening. Record this value.

5. Calculate air flow in cubic feet per minute (CFM) by multiplying the face velocity by the area of the opening. (This value will be of use to technicians adjusting fan unit)

6. Raise or lower the sash until the reading is between 100 and 120 linear feet per minute.

7. Mentally divide the face opening of the hood into ten areas. Record the face velocity reading at the center of each of the nine areas. Compute the average face velocity.

8. Measure the area of the opening of the hood. Record this as the Access Opening.

9. Calculate air flow in cubic feet per minute (CFM) by multiplying the average face velocity by the area of the access opening. (Again, this value will be of use to technicians adjusting fan unit)

10. Record the highest sash height at which an average face velocity of 100 FPM is attained. This will be called the Maximum Safe Operation Height.

11. If the hood is unable to create an average face velocity of 100 FPM at a sash height of 15 or 10 inches, the unit fails and will be labeled "CAUTION - DO NOT USE THIS HOOD." Location of the hood and results of certification test will be forwarded to the campus facilities management or physical plant for repair.

12. If the hood is unable to create an average face velocity of 100 FPM at a sash height of 15 inches but is able to at a sash height of not less than 10 inches, then hood will be conditionally certified for operation at the appropriate sash height. Campus facilities management or physical plant office will be notified of the conditional certification and look into repairs or maintenance to increase unit`s efficiency.

13. If the hood is able to create an average face velocity of 100 FPM at or above a 15 inch sash height, hood will be certified at the sash height which generates a minimum of 100 FPM.

14. Following any repairs or scheduled preventative maintenance, the above procedures are repeated. If a fume hood's performance is still inadequate, facilities management will be requested to make further adjustments. If all efforts fail to bring a fume hood into an effective standard of performance, an outside consultant or repair firm may be obtained or the hood will be replaced.

NOTE: The University of Maine System has some older hoods intended for use in chemistry laboratories that do not have a movable sash or are set up for installation of a sash. These hoods shall be tested in the same way with an average velocity of 60 linear feet per minute being the level which a hood must attain to be certified for use. Hoods with velocities less than 60 lfpm will not be certified and there is no conditional certification for these types of hoods.

STEP 3: SMOKE TEST

1.Using smoke as an indicator (commercially available ventilation smoke tubes or kits), note airflow patterns to determine if there is a leak in the hood containment or if there is turbulence that renders the hood ineffective.

2. Any failure of unit to contain and exhaust test smoke should be labeled "Do Not Use," noted, and reported to campus facilities management or physical plant for correction.

Dry Ice Test (optional)

This test is recommended for fume hoods which will be used with hazardous chemicals that evolve vapors that are heavier than air.

1. While hood is activated, place some dry ice in a bowl of warm water inside the hood. Observe smoke that is produced. If smoke is not contained and exhausted by the unit, campus facilities management or physical plant shall be notified for corrective action.

APPENDIX F

SEMI-ANNUAL PREVENTIVE MAINTENANCE PLAN FOR LABORATORY FUME HOODS

Preventive maintenance will be performed twice a year by facilities management or physical plant on all laboratory fume hood exhaust systems. Building occupants or users of fume hoods will be responsible for ensuring that the hood unit itself is routinely cleaned and maintained. This includes but is not limited to ensuring burned out light bulbs are replaced, sash guides, pulleys, and cables are lubricated (as required), wiping interior walls and counter tops on a routine basis and reporting any problems with any aspect of the hood or exhaust system to their facilities management or physical plant office.

Preventive maintenance should include but is not limited to:

1) checking motor bearings for wear

2) fan bearing inspection and lubrication

3) replacing worn, damaged, cracked or nonfunctioning parts

4) visual inspection of duct work to ensure there is no deterioration or leakage.

5) checking of all electrical connections for deterioration and proper wiring.

6) Ensure belts, moving parts, and electrical connections are guarded or shielded.

and may also include (especially during trouble shooting):

7) checking motor amperage and/or rpm

8) smoke testing to determine leaks in ductwork and/or which motor is attached to which duct

9) cleaning duct work of accumulated deposits or obstructions.

10) oil all motors

11) changing air filters

12) check all fire and/or control dampers, turning veins, louvers and screens.

Safety precautions should be taken by all personnel performing preventive maintenance. Maintenance personnel should ensure each laboratory fume hood being worked on is locked out or tagged out to prevent usage during maintenance procedures. Building occupants or hood users, where necessary, may have to stop work or use of the hood during preventative maintenance or repair work.

SAFETY PRECAUTIONS DURING PREVENTATIVE MAINTENANCE

1) No hazardous work or experiments may be conducted in a laboratory hood during any maintenance work on the system.

2) Laboratory hood(s) and all mechanical and electrical systems shall be locked out and/or tagged out during maintenance or repair work. This is to prevent injury from accidental start-up or operation.

3) If duct cleaning is necessary, prior to the cleaning, hood user(s) must clean and decontaminate the hood area and remove all substances and items.

4) Any hood used for radiologically based work will be evaluated for any potential hazard prior to cleaning or maintenance.

5) Maintenance personnel performing hood and duct cleaning must wear proper respirators and gloves.

6) All waste from hood cleaning shall be disposed of as hazardous waste at an approved landfill.

7) If there are any questions or doubts from maintenance personnel regarding the materials used and/or contaminating the duct work or exhaust system, they should contact University safety personnel.

APPENDIX G

RECOMMENDATIONS FOR NEW LABORATORY HOODS

University of Maine System Office of Facilities should be informed of all proposed or planned laboratory hood installations. Office of Facilities recommends conforming with NFPA, ASHRAE, SAMA, and ACGIH standards and may assist in the evaluation of the selection and design of all fume hoods before they are installed. The following are select specifications that should be adhered to in the installation of new laboratory fume hoods.

PLANNING CONSIDERATIONS

1. Room air, make up air, auxiliary air (if used), and pollution control devices (if used) are integral parts of a properly operating laboratory fume hood system and must be considered when designing a fume removal system. (SAMA LF-10, 1980)

2. Laboratory fume hood exhaust systems should be coordinated with room exhaust systems and may be used in conjunction with room exhaust to provide the necessary room ventilation. (SAMA LF-10 B2.1, 1980)

3. Laboratory fume hoods should be located within the laboratory to avoid cross currents at the fume hood face due to heating, cooling or ventilating inlets.(SAMA LF-10 B2.2, 1980)

4. Laboratory hoods shall be located in areas of minimum turbulence. They should <u>not</u> be located adjacent to a single means of access to an exit and or high traffic areas. (NFPA 45 6-10, 1986)

5. A second means of access to an exit shall be provided from a laboratory work area if a hood is located adjacent to a primary means of exit access. (NFPA 45 3-4.1, 1986)

FAN OR BLOWER CONSIDERATIONS

1. All hoods should be ducted and have the exhaust fan located on the roof of the building to provide a negative pressure in that portion of the duct system located within the building (SAMA LF-10 B4.1, 1980) Exhaust fans may be located in penthouses as long as any part of the duct system that is under positive pressure is sealed and routinely inspected for leakage.

2. Exhaust fans shall be sized to exhaust the volume of air necessary to attain the selected fume hood face velocity. (SAMA LF-10 B4.2, 1980)
3. Fans shall be selected to meet fire, explosion, and corrosion requirements.(NFPA 45 6-8.1, 1986)

4. Fans conveying both corrosive and flammable or combustible materials may be lined with or constructed of corrosion-resistant materials having a flame spread index of 25 or less. (NFPA 45 6-8.2, 1986)

5. Fans shall be located and arranged so as to afford ready access for repairs, cleaning, inspection, and maintenance. (NFPA 45 6-8.3, 1986)

6. If exhaust air is to pass through the fans, the rotating element shall be constructed of nonferrous or nonsparking material. Alternatively, the casing shall be constructed of or lined with such material. Where there is the possibility of solid material passing through the fan that would produce spark, both the rotating element and the casing shall be constructed of such material. Nonferrous or nonsparking materials shall have a flame spread index of 25 or less. (NFPA 45 6-8.4, 1986)

7. Motors and their controls shall be located outside the location where flammable or combustible vapors or combustible dusts are generated or conveyed unless specifically approved for the location and use. (NFPA 45 6-8.5,1986)

8. Fans shall be labeled with an arrow indicating the proper direction of rotation and the location of laboratory hoods and exhaust systems served. (NFPA 45 6-8.6)

DUCT AND EXHAUST AIRFLOW CONSIDERATIONS

1. Air exhausted from laboratory hoods shall not be recirculated. (NFPA 45 6-5.1, 1986)

2. If energy conservation devices are used, they shall not recirculate laboratory exhaust air or otherwise compromise the safety of the laboratory hood. Energy conservation devices designed to recover latent heat shall not be used in the laboratory hood exhaust systems that could contain flammable or toxic chemicals due to risk of returning contaminants to fresh air supply. (NFPA 45 6-5.2, 1986)

3. Air exhausted from laboratory work areas shall not pass through other areas unducted. (NFPA 45 6-5.3, 1986)

4. All duct systems exhausting laboratory hoods must maintain a negative pressure relative to pressure of other normally occupied areas of the building. (NFPA 45 6-5.4, 1986)

5. Duct velocities shall be high enough to minimize deposition of materials in exhaust system. (NFPA 45 6-7, 1986)

6. Where possible, ducts shall be constructed entirely of noncombustible materials. If not possible, combustible ducts and duct linings that have a flame spread index of 25 or less may be used. Materials that have a flame spread index of 25 or less shall also be used for vibration isolation. (NFPA 45 6-6, 1986)

EXHAUST STACK CONSIDERATIONS

1. Exhaust stacks are to extend 7 feet above the highest point on the roof line. Location of stack and exhaust velocity must be considered and be sufficient to prevent reentry of hazardous chemicals into the building. (NFPA 45 6-8.7)

2. Exhaust stack should be designed in an offset style. Weather caps or shields should not be installed over the stack. (SAMA LF-10, E6)

LABORATORY FUME HOOD UNIT CONSIDERATIONS

1. Laboratory hood face velocities shall be sufficient to meet University certification standards and to prevent the escape of contaminants generated in the hood. Certification must occur prior to use of the hood following installation and/or changes to the system. (see Appendix E)

2. Light fixture(s) mounted inside the hood liner shall be protected against corrosion and shall be vapor proof or explosion proof according to appropriate specifications. (SAMA LF-10, 1980)

3. Light fixtures mounted exterior to the hood liner shall be protected from the hood interior by a sealed, transparent, impact resistant vapor shield. Material used shall have a flame spread index of 25 or less. Access for relamping or cleaning should be from the exterior. (SAMA LF-10, 1980)

4. Work surfaces inside hood shall be designed to contain spills. (SAMA LF-10, 1980 & NFPA 45 6-9, 1986)

5. Laboratory hood bench tops should be 22 to 28 inches deep. Smaller depths confine work space and larger depths pose ergonomic concerns.

6. Table top inside laboratory hood shall extend a minimum of 3 inches beyond the sash.

7. Laboratory fume hoods should be equipped with airfoils to assist in reducing turbulent airflow at the face of the hood.

8. Hood unit should contain liner material(s) that have a flame spread index of less than 25. (SAMA LF-10, 1980 & NFPA 45 6-9)

9. Laboratory hood unit should have adjustable sashes that may be used to increase the face velocity or as a safety shield. The sash shall be glazed with material that will provide the operator or environment protection against hazards normally associated with the use of the hood.(NFPA 45, 1986)

CONTROL CONSIDERATIONS

1. Controls and dampers, where required for balancing or control of the exhaust system, shall be of a type that, in the event of failure, fall in an open position to assure a continuous draft.

2. Each hood should be equipped with a manometer or similar device to give indication of unit performing properly. This may be purchased as an option on many hood units or installed directly into the duct system during installation.

3. If not already a part of the hood unit, switches for fan motor and lights in hood shall be located outside of the hood in a location near the hood being served. All switches must be labeled as to their function.

Appendix H: Occupational exposure to hazardous chemicals in laboratories.

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10106&p_table=STANDARDS

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** Z
- **Subpart Title:** Toxic and Hazardous Substances
- **Standard Number:** 1910.1450
- **Title:** Occupational exposure to hazardous chemicals in laboratories.
- **Appendix:** A , B
- **GPO Source:** e-CFR

1910.1450(a)

Scope and application.

1910.1450(a)(1)

This section shall apply to all employers engaged in the laboratory use of hazardous chemicals as defined below.

1910.1450(a)(2)

Where this section applies, it shall supersede, for laboratories, the requirements of all other OSHA health standards in 29 CFR part 1910, subpart Z, except as follows:

1910.1450(a)(2)(i)

For any OSHA health standard, only the requirement to limit employee exposure to the specific permissible exposure limit shall apply for laboratories, unless that particular standard states otherwise or unless the conditions of paragraph (a)(2)(iii) of this section apply.

1910.1450(a)(2)(ii)

Prohibition of eye and skin contact where specified by any OSHA health standard shall be observed.

1910.1450(a)(2)(iii)

Where the action level (or in the absence of an action level, the permissible exposure limit) is routinely exceeded for an OSHA regulated substance with exposure monitoring and medical surveillance requirements paragraphs (d) and (g)(1)(ii) of this section shall apply.

1910.1450(a)(3)

This section shall not apply to:

1910.1450(a)(3)(i)

Uses of hazardous chemicals which do not meet the definition of laboratory use, and in such cases, the employer shall comply with the relevant standard in 29 CFR part 1910, subpart Z, even if such use occurs in a laboratory.

1910.1450(a)(3)(ii)

Laboratory uses of hazardous chemicals which provide no potential for employee exposure. Examples of such conditions might include:

1910.1450(a)(3)(ii)(A)

Procedures using chemically-impregnated test media such as Dip-and-Read tests where a reagent strip is dipped into the specimen to be tested and the results are interpreted by comparing the color reaction to a color chart supplied by the manufacturer of the test strip; and

1910.1450(a)(3)(ii)(B)

Commercially prepared kits such as those used in performing pregnancy tests in which all of the reagents needed to conduct the test are contained in the kit.

1910.1450(b)

Definitions —

Action level means a concentration designated in 29 CFR part 1910 for a specific substance, calculated as an eight (8)-hour time-weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

Assistant Secretary means the Assistant Secretary of Labor for Occupational Safety and Health, U.S. Department of Labor, or designee.

Carcinogen (see *select carcinogen*).

Chemical Hygiene Officer means an employee who is designated by the employer, and who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan. This definition is not intended to place limitations on the position description or job classification that the designated indvidual shall hold within the employer's organizational structure.

Chemical Hygiene Plan means a written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment and work practices that (i) are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and (ii) meets the requirements of paragraph (e) of this section.

Emergency means any occurrence such as, but not limited to, equipment failure, rupture of containers or failure of control equipment which results in an uncontrolled release of a hazardous chemical into the workplace.

Employee means an individual employed in a laboratory workplace who may be exposed to hazardous chemicals in the course of his or her assignments.

Hazardous chemical means any chemical which is classified as health hazard or simple asphyxiant in accordance with the Hazard Communication Standard (§1910.1200).

Health hazard means a chemical that is classified as posing one of the following hazardous effects: Acute toxicity (any route of exposure); skin corrosion or irritation; serious eye damage or eye irritation; respiratory or skin sensitization; germ cell mutagenicity; carcinogenity; reproductive toxicity; specific target organ toxicity (single or repeated exposure); aspiration hazard. The criteria for determining whether a chemical is classified as a health hazard are detailed in appendix A of the Hazard Communication Standard (§1910.1200) and §1910.1200(c) (definition of "simple asphyxiant").

Laboratory means a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

Laboratory scale means work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.

Laboratory-type hood means a device located in a laboratory, enclosure on five sides with a moveable sash or fixed partial enclosed on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.

Walk-in hoods with adjustable sashes meet the above definition provided that the sashes are adjusted during use so that the airflow and the exhaust of air contaminants are not compromised and employees do not work inside the enclosure during the release of airborne hazardous chemicals.

Laboratory use of hazardous chemicals means handling or use of such chemicals in which all of the following conditions are met:

(i) Chemical manipulations are carried out on a "laboratory scale;"

(ii) Multiple chemical procedures or chemicals are used;

(iii) The procedures involved are not part of a production process, nor in any way simulate a production process; and

(iv) "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

Medical consultation means a consultation which takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.

Mutagen means chemicals that cause permanent changes in the amount or structure of the genetic material in a cell. Chemicals classified as mutagens in accordance with the Hazard Communication Standard (§1910.1200) shall be considered mutagens for purposes of this section.

Physical hazard means a chemical that is classified as posing one of the following hazardous effects: Explosive; flammable (gases, aerosols, liquids, or solids); oxidizer (liquid, solid, or gas); self reactive; pyrophoric (gas, liquid or solid); self-heating; organic peroxide; corrosive to metal; gas under pressure; in contact with water emits flammable gas; or combustible dust. The criteria for determining whether a chemical is classified as a physical hazard are in appendix B of the Hazard Communication Standard (§1910.1200) and §1910.1200(c) (definitions of "combustible dust" and "pyrophoric gas").

Protective laboratory practices and equipment means those laboratory procedures, practices and equipment accepted by laboratory health and safety experts as effective, or that the employer can show to be effective, in minimizing the potential for employee exposure to hazardous chemicals.

Reproductive toxins mean chemicals that affect the reproductive capabilities including adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on the development of the offspring. Chemicals classified as reproductive toxins in accordance with the Hazard Communication Standard (§1910.1200) shall be considered reproductive toxins for purposes of this section.

Select carcinogen means any substance which meets one of the following criteria:

(i) It is regulated by OSHA as a carcinogen; or

(ii) It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or

(iii) It is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer Monographs (IARC) (latest editions); or

(iv) It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:

(A) After inhalation exposure of 6–7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m^3;

(B) After repeated skin application of less than 300 (mg/kg of body weight) per week; or

(C) After oral dosages of less than 50 mg/kg of body weight per day.

1910.1450(c)

Permissible exposure limits. For laboratory uses of OSHA regulated substances, the employer shall assure that laboratory employees' exposures to such substances do not exceed the permissible exposure limits specified in 29 CFR part 1910, subpart Z.

1910.1450(d)

Employee exposure determination --

1910.1450(d)(1)

Initial monitoring. The employer shall measure the employee's exposure to any substance regulated by a standard which requires monitoring if there is reason to believe that exposure levels for that substance routinely exceed the action level (or in the absence of an action level, the PEL).

1910.1450(d)(2)

Periodic monitoring. If the initial monitoring prescribed by paragraph (d)(1) of this section discloses employee exposure over the action level (or in the absence of an action level, the PEL), the employer shall immediately comply with the exposure monitoring provisions of the relevant standard.

1910.1450(d)(3)

Termination of monitoring. Monitoring may be terminated in accordance with the relevant standard.

1910.1450(d)(4)

Employee notification of monitoring results. The employer shall, within 15 working days after the receipt of any monitoring results, notify the employee of these results in writing either individually or by posting results in an appropriate location that is accessible to employees.

1910.1450(e)

Chemical hygiene plan -- General. (Appendix A of this section is non-mandatory but provides guidance to assist employers in the development of the Chemical Hygiene Plan).

1910.1450(e)(1)

Where hazardous chemicals as defined by this standard are used in the workplace, the employer shall develop and carry out the provisions of a written Chemical Hygiene Plan which is:

1910.1450(e)(1)(i)

Capable of protecting employees from health hazards associated with hazardous chemicals in that laboratory and

1910.1450(e)(1)(ii)

Capable of keeping exposures below the limits specified in paragraph (c) of this section.

1910.1450(e)(2)

The Chemical Hygiene Plan shall be readily available to employees, employee representatives and, upon request, to the Assistant Secretary.

1910.1450(e)(3)

The Chemical Hygiene Plan shall include each of the following elements and shall indicate specific measures that the employer will take to ensure laboratory employee protection;

1910.1450(e)(3)(i)

Standard operating procedures relevant to safety and health considerations to be followed when laboratory work involves the use of hazardous chemicals;

1910.1450(e)(3)(ii)

Criteria that the employer will use to determine and implement control measures to reduce employee exposure to hazardous chemicals including engineering controls, the use of personal protective equipment and hygiene practices; particular attention shall be given to the selection of control measures for chemicals that are known to be extremely hazardous;

1910.1450(e)(3)(iii)

A requirement that fume hoods and other protective equipment are functioning properly and specific measures that shall be taken to ensure proper and adequate performance of such equipment;

1910.1450(e)(3)(iv)

Provisions for employee information and training as prescribed in paragraph (f) of this section;

1910.1450(e)(3)(v)

The circumstances under which a particular laboratory operation, procedure or activity shall require prior approval from the employer or the employer's designee before implementation;

1910.1450(e)(3)(vi)

Provisions for medical consultation and medical examinations in accordance with paragraph (g) of this section;

1910.1450(e)(3)(vii)

Designation of personnel responsible for implementation of the Chemical Hygiene Plan including the assignment of a Chemical Hygiene Officer, and, if appropriate, establishment of a Chemical Hygiene Committee; and

1910.1450(e)(3)(viii)

Provisions for additional employee protection for work with particularly hazardous substances. These include "select carcinogens," reproductive toxins and substances which have a high degree of acute toxicity. Specific consideration shall be given to the following provisions which shall be included where appropriate:

1910.1450(e)(3)(viii)(A)

Establishment of a designated area;

1910.1450(e)(3)(viii)(B)

Use of containment devices such as fume hoods or glove boxes;

1910.1450(e)(3)(viii)(C)

Procedures for safe removal of contaminated waste; and

1910.1450(e)(3)(viii)(D)

Decontamination procedures.

1910.1450(e)(4)

The employer shall review and evaluate the effectiveness of the Chemical Hygiene Plan at least annually and update it as necessary.

1910.1450(f)

Employee information and training.

1910.1450(f)(1)

The employer shall provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work area.

1910.1450(f)(2)

Such information shall be provided at the time of an employee's initial assignment to a work area where hazardous chemicals are present and prior to assignments involving new exposure situations. The frequency of refresher information and training shall be determined by the employer.

1910.1450(f)(3)

Information. Employees shall be informed of:

1910.1450(f)(3)(i)

The contents of this standard and its appendices which shall be made available to employees;

1910.1450(f)(3)(ii)

the location and availability of the employer's Chemical Hygiene Plan;

1910.1450(f)(3)(iii)

The permissible exposure limits for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard;

1910.1450(f)(3)(iv)

Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory; and

1910.1450(f)(3)(v)

The location and availability of known reference material on the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including, but not limited to, safety data sheets received from the chemical supplier.

1910.1450(f)(4)

Training.

1910.1450(f)(4)(i)

Employee training shall include:

1910.1450(f)(4)(i)(A)

Methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.);

1910.1450(f)(4)(i)(B)

The physical and health hazards of chemicals in the work area; and

1910.1450(f)(4)(i)(C)

The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used.

1910.1450(f)(4)(ii)

The employee shall be trained on the applicable details of the employer's written Chemical Hygiene Plan.

1910.1450(g)

Medical consultation and medical examinations.

1910.1450(g)(1)

The employer shall provide all employees who work with hazardous chemicals an opportunity to receive medical attention, including any follow-up examinations which the examining physician determines to be necessary, under the following circumstances:

1910.1450(g)(1)(i)

Whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory, the employee shall be provided an opportunity to receive an appropriate medical examination.

1910.1450(g)(1)(ii)

Where exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the PEL) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance shall be established for the affected employee as prescribed by the particular standard.

1910.1450(g)(1)(iii)

Whenever an event takes place in the work area such as a spill, leak, explosion or other occurrence resulting in the likelihood of a hazardous exposure, the affected employee shall be provided an opportunity for a medical consultation. Such consultation shall be for the purpose of determining the need for a medical examination.

1910.1450(g)(2)

All medical examinations and consultations shall be performed by or under the direct supervision of a licensed physician and shall be provided without cost to the employee, without loss of pay and at a reasonable time and place.

1910.1450(g)(3)

Information provided to the physician. The employer shall provide the following information to the physician:

1910.1450(g)(3)(i)

The identity of the hazardous chemical(s) to which the employee may have been exposed;

1910.1450(g)(3)(ii)

A description of the conditions under which the exposure occurred including quantitative exposure data, if available; and

1910.1450(g)(3)(iii)

A description of the signs and symptoms of exposure that the employee is experiencing, if any.

1910.1450(g)(4)

Physician's written opinion.

1910.1450(g)(4)(i)

For examination or consultation required under this standard, the employer shall obtain a written opinion from the examining physician which shall include the following:

1910.1450(g)(4)(i)(A)

Any recommendation for further medical follow-up;

1910.1450(g)(4)(i)(B)

The results of the medical examination and any associated tests;

1910.1450(g)(4)(i)(C)

Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous workplace; and

1910.1450(g)(4)(i)(D)

A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

1910.1450(g)(4)(ii)

The written opinion shall not reveal specific findings of diagnoses unrelated to occupational exposure.

1910.1450(h)

Hazard identification.

1910.1450(h)(1)

With respect to labels and safety data sheets:

1910.1450(h)(1)(i)

Employers shall ensure that labels on incoming containers of hazardous chemicals are not removed or defaced.

1910.1450(h)(1)(ii)

Employers shall maintain any safety data sheets that are received with incoming shipments of hazardous chemicals, and ensure that they are readily accessible to laboratory employees.

1910.1450(h)(2)

The following provisions shall apply to chemical substances developed in the laboratory:

1910.1450(h)(2)(i)

If the composition of the chemical substance which is produced exclusively for the laboratory's use is known, the employer shall determine if it is a hazardous chemical as defined in paragraph (b) of this section. If the chemical is determined to be hazardous, the employer shall provide appropriate training as required under paragraph (f) of this section.

1910.1450(h)(2)(ii)

If the chemical produced is a byproduct whose composition is not known, the employer shall assume that the substance is hazardous and shall implement paragraph (e) of this section.

1910.1450(h)(2)(iii)

If the chemical substance is produced for another user outside of the laboratory, the employer shall comply with the Hazard Communication Standard (29 CFR 1910.1200) including the requirements for preparation of safety data sheets and labeling.

1910.1450(i)

Use of respirators. Where the use of respirators is necessary to maintain exposure below permissible exposure limits, the employer shall provide, at no cost to the employee, the proper respiratory equipment. Respirators shall be selected and used in accordance with the requirements of 29 CFR 1910.134.

1910.1450(j)

Recordkeeping.

1910.1450(j)(1)

The employer shall establish and maintain for each employee an accurate record of any measurements taken to monitor employee exposures and any medical consultation and examinations including tests or written opinions required by this standard.

1910.1450(j)(2)

The employer shall assure that such records are kept, transferred, and made available in accordance with 29 CFR 1910.1020.

1910.1450(k)

[Reserved]

1910.1450(l)

Appendices. The information contained in the appendices is not intended, by itself, to create any additional obligations not otherwise imposed or to detract from any existing obligation.

[55 FR 3327, Jan. 31, 1990; 55 FR 7967, March, 6, 1990; 55 FR 12777, March 30, 1990; 61 FR 5507, Feb. 13, 1996; 71 FR 16674, April 3, 2006; 77 FR 17887, March 26, 2012]

Appendix I: Hazardous Waste Disposal Program

HAZARDOUS WASTE DISPOSAL PROGRAM

PROCEDURES FOR DISPOSING OF CHEMICALS IN LABORATORIES

Proper disposal of the substances they use is an important responsibility of all laboratory workers. Arrangements for disposal may vary from laboratory to laboratory, depending on the facilities and the types of substances used, but the basic principle is that substances must be disposed of in ways that avoid harm to people and the environment. Wastes should be transferred in a form that is safe and acceptable to the people involved in disposal operations. Considering the future fate of the waste substance is very important.

Generally hazardous waste will be placed in Folsom 103B in the cabinet designated for Hazardous waste, or in a designated temporary storage area in each laboratory. Materials in the temporary areas will be picked up by the Chemical Hygiene Officer, taken for storage in Folsom 103B, and entered into a hazardous waste manifest awaiting pick-up by a hazardous waste transfer company (e.g. Lab-Pak, Inc).

All laboratory workers and students collecting hazardous materials must follow these instructions:

The waste must be in a closed container and marked with the following information:

- Labeled *hazardous waste* (stickers are available in each laboratory)
- Hazardous material(s) enclosed in the container- chemicals [concentrations when known]
- Date
- Initials

Please inform the Chemical Hygiene Officer of any hazardous waste materials being stored in your laboratory so that they can be picked up and transported to the storage area awaiting transfer.

GENERAL CONSIDERATIONS

The plan for safe disposal of the substances used is as much a part of the plan for the experiment as is the acquisition of materials, the experimental procedures, and the isolation or storage. If an experiment involves new types of disposal problems, the laboratory worker should discuss the disposal plan with the laboratory supervisor (or department head) and, if necessary the safety coordinator or hazardous waste coordinator for your campus.

If practical, very hazardous substances should be converted to less hazardous substances in the laboratory rather than being placed directly in containers. For example, strong carcinogens should be oxidized in solution in the laboratory before disposal, and highly reactive substances, such as metallic sodium and peroxides, should be converted to less reactive substances. Reactions may be moderated by dilution, cooling, or the slow addition of a neutralizing agent. For water-miscible materials, pouring the reaction mixture onto a bed of ice can often be a way to cool and dilute it simultaneously.

All persons using chemicals in the laboratory should be generally aware of the toxic properties of the substance(s) used, including consideration of the toxic properties of possible reaction products. If the toxic properties of possible products are not known, the products should be treated with respect and the disposal method should take account of the uncertain hazards. Some products may be disposed of as an integral part of the experiment (e.g., by using a scrubber for a gaseous product).

The cleanup of a laboratory that has been damaged by fire may present special hazards, e.g., the presence of toxic chemicals in the atmosphere and work environment, and may require special precautions.

The disposal of chemicals from instructional laboratories is a special problem because the students in such laboratories are inexperienced, the quantities of wastes may be relatively large, and the facilities may not be optimum. Education of students about how to handle chemicals and dispose of them safely is an integral part of their laboratory training.

DISPOSAL TO THE SEWER SYSTEM

Sewer systems operate in various ways, and some of them may be harmed or may present hazards for people and the environment when some chemicals are added directly to them. Generally, there are local regulations about what may be poured down the drain. The laboratory supervisor should know the local regulations and communicate this information to the laboratory workers so that they can conform to the regulations. All laboratory workers should know and respect these regulations. For sewer systems that discharge into waterways, federal regulations limit the disposal of certain toxic chemicals. In general, the following rules regarding disposal into a sewer system should be followed:

1. Only water-soluble substances should be disposed of in the laboratory sink. Solutions of flammable solvents (i.e., alcohols) must be sufficiently dilute that they do not pose a fire hazard.

2. Strong acids and bases should be diluted to the pH 4-10 range before they are poured in the sewer system. Acids and alkalis should not be poured in the sewer drain at a rate exceeding the equivalent of 50 ml of concentrated substance per minute (with water).

3. Highly toxic, malodorous, or lachrymatory chemicals should not be disposed of down the drain. Laboratory drains are generally interconnected; a substance that goes down one sink may well come up as a vapor in another. Sinks are usually communal property, and there is a very real hazard of chemicals from two sources contacting one another; the sulfide poured into one drain may contact the acid poured into another, with unpleasant consequences for all in the building. Some simple reactions can even cause explosions (e.g., ammonia plus iodine, silver nitrate plus ethanol, or picric acid plus lead salts).

4. Heavy metal compounds should never be disposed of in the sink. They may pose a hazard for the sewer system or someone else's water supply.

DISPOSAL OF SOLID CHEMICAL WASTES

Your campus should have procedures for collecting solid chemical wastes from the laboratories and arranging for disposal by the proper organizations. These procedures will be placed in this section once they are formalized. They should include a clear understanding as to who is in charge and what the responsibilities of the laboratory workers are with respect to the identification of hazards that may be encountered in handling, transporting, and disposing of the solid waste. The people picking up such material should be aware of the hazards and know what to do in case of a spill during transportation.

The solid chemical wastes of a laboratory should be placed in containers provided for that purpose. When bottles are used, they should be placed in buckets. Ensuring that all wastes are adequately labeled is very important. The laboratory worker should be aware of the hazards that may be involved in disposing of particular solid chemical wastes and the importance of segregating incompatible materials.

DISPOSAL OF LIQUID CHEMICAL WASTES

Similar to the requirements for solid chemical wastes, your campus should have a procedure for collecting liquid chemical wastes from the laboratories and arranging for their disposal by the proper organizations. Suitable containers should be provided, and the laboratory workers should understand what may, or may not, be placed in these containers and which materials require special labeling.

Waste solvents that are free of solids and corrosive or reactive substances may be collected in a common bottle or can, which is taken away when full. If this system is used, it is essential to consider exactly what mixtures will go into the can and whether the substances involved are compatible (this may include waste from the neighboring laboratory). Segregation into two or three types of waste is often useful (e.g., chlorinated solvents, hydrocarbons), as is the use of completely separate bottles for waste that poses special difficulties. In particular, because chlorinated solvents for hydrogen chloride on combustion, they often must be segregated from materials destined for incineration as their burning will violate local air pollution ordinances. Generally speaking, separated and well-defined waste is easier to dispose of and, if an outside contractor is used, less expensive. All wastes posing hazards should be so labeled.

Some solvents (such as ether and secondary alcohols) form explosive peroxides on standing. Some reactions can cause explosions directly (e.g., acetone plus chloroform in the presence of a base). Others, such as acid-base interactions, can generate sufficient heat to vaporize or ignite flammable materials such as carbon disulfide. The addition of hot materials can cause the buildup of pressure in a tightly closed solvent container, with the potential for compressive ignition. The acid formed when halogenated solvents are left moist can corrode cans, as can any dissolved corrosive in a discarded mixture.

When large quantities of a solvent are involved, consideration should be given to recycling rather that disposal. This operation also involves some potential hazard and expense, but these limitations may be less severe than those for disposal, especially as disposal costs are expensive and are increasing.

DISPOSAL OF ESPECIALLY HAZARDOUS WASTES

This class of chemical wastes includes very toxic substances, strong carcinogens, mutagens, nerve gases, explosives, and substances in tanks and other sealed containers. The laboratory worker has the responsibility to ensure that proper arrangements for disposal of these materials are made. Wherever possible, chemical reaction in the laboratory to produce less hazardous substances should be undertaken. For the case of those chemicals regulated as carcinogens, EPA disposal rules must be followed.

A spill of one of these substances can be an especially serious hazard. Personnel working with such substances should have contingency plans, equipment, and materials available for coping with potential accidents (see Appendix A-11 and A-12).

SPILLS (Also found as Appendix A-11)

Experience has shown that the accidental release of hazardous substances is a common enough occurrence to require preplanning for procedures that will minimize exposure of personnel and property. Such procedures may range from having available a sponge mop and bucket to having an emergency spill-response team, complete with the appropriate protective apparel, safety equipment, and materials to contain, confine, dissipate, and clean up the spill.

The preplanning should include consideration of the following factors:

1. Potential location of the release (e.g., outdoors vs. indoors; in a laboratory, corridor, or storage area, on a table, in a hood, or on the floor).
2. The quantities of material that might be released and whether the substance is a piped material or a compressed gas.
3. Chemical and physical properties of the material (e.g., its physical state, vapor pressure, and air or water reactivity).
4. Hazardous properties of the material (its toxicity, corrosivity, and flammability)
5. The types of personal protective equipment that might be needed.

In any event, there should be supplies and equipment on hand to deal with the spill, consistent with the hazards and quantities of the spilled substance. These cleanup supplies should include neutralizing agents (such as sodium carbonate and sodium bisulfate) and adsorbents (such as vermiculite and sand). Paper towels and sponges may also be used as absorbent-type cleanup aids, although this should be done cautiously. For example, paper towels used to clean up a spilled oxidizer may later ignite, and appropriate gloves should be worn when wiping up highly toxic materials with paper towels. Also, when a spilled flammable solvent is absorbed in vermiculite or sand, the resultant solid is highly flammable and gives off flammable vapors and, thus, must be properly contained or removed to a safe place.

Commercial spill kits are available that have instructions, adsorbents, reactants, and protective equipment. These kits may be located strategically around work areas much as fire extinguishers are.

If a spill does occur, the following general procedures may be used but should be tailored to individual needs (**if mercury- **see Appendix A-12 Small-Scale Mercury Response**, below):

1. Attend to any persons who may have been contaminated.
2. Notify persons in the immediate area about the spill.
3. Evacuate all nonessential personnel from the spill area.
4. If the spilled material is flammable, turn off all ignition and heat sources.
5. Avoid breathing vapors of the spilled materials; if necessary, use a respirator (only if you have been trained and tested in its use).
6. Leave on or establish exhaust ventilation if it is safe to do so.
7. Secure proper supplies to effect clean up.
8. During cleanup wear appropriate apparel.
9. Notify Facilities Management, your department and the campus chemical hygiene officer.
10. Log the spill in the Spill Log provided in each laboratory.

Handling of Spilled Liquids

1. Confine or contain the spill to a small area. Do not let it spread.
2. For small quantities of inorganic acids or bases, use a neutralizing agent or an absorbent mixture (e.g., soda ash or diatomaceous earth). For small quantities of other materials, absorb the spill with a non-reactive material (such as vermiculite, dry sand, or towels.

3. For larger amounts of inorganic acids and bases, flush with large amounts of water (provided that the water will not cause additional damage). Flooding is not recommended in storerooms where violent spattering may cause additional hazards or in areas where water-reactive chemicals may be present.

4. Mop up the spill, wringing out the mop in a sink or a pail equipped with rollers.

5. Carefully pick up and clean any cartons or bottles that have been splashed or immersed.

6. Vacuum the area with a vacuum cleaner approved for the material involved, remembering that the exhaust of a vacuum cleaner can create aerosols and, thus, should be vented to a hood or through a filter.

7. If the spilled material is extremely volatile, let it evaporate and be exhausted by the mechanical ventilation system (provided that the hood and associated mechanical system is spark-proof).

8. Dispose of residues according to safe disposal procedures.

9. Log the spill in the Spill Log provided in each laboratory.

Handling of Spilled Solids

Generally, sweep spilled solids of low toxicity into a dust pan and place them in a solid-waste container for disposal. Additional precautions such as the use of a vacuum cleaner equipped with a HEPA filter may be necessary when cleaning up spills of more highly toxic solids.

Handling of Leaking Compressed Gas Cylinders

Occasionally, a cylinder or one of its component parts develops a leak. Most such leaks occur at the top of the cylinder in areas such as the valve threads, safety device, valve stem, and valve outlet.

If a leak is suspected, do not use a flame for detection; rather a flammable-gas leak detector or soapy water or other suitable solution should be used. If the leak cannot be remedied by tightening a valve gland or a packing nut, emergency action procedures should be effected and the supplier should be notified. Laboratory workers should never attempt to repair a leak in the valve threads or safety device; rather, they should consult the supplier for instructions.

The following general procedures can be used for leaks of minimum size where the indicated action can be taken without serious exposure of personnel.

If it is necessary to move a leaking cylinder through populated portions of the building, place a plastic bag, rubber shroud, or similar device over the top and tape it (duct tape is preferred) to the cylinder to confine the leaking gas.

1. Flammable, inert, or oxidizing gases - Move the cylinder to an isolated area (away from combustible material if the gas is flammable or an oxidizing agent) and post signs that describe the hazards and state warnings.

2. Corrosive gases may increase the size of the leak as they are released and some corrosives are also oxidants or flammable - Move the cylinder to an isolated, well-ventilated area and use suitable means to direct the gas into an appropriate chemical neutralizer. Post signs that describe the hazards and state warnings.

3. Toxic gases - Follow the same procedure as for corrosive gases. Move the cylinder to an isolated, well ventilated area and use suitable means to direct the gas into an appropriate chemical neutralizer. Post signs that describe the hazards and state the warnings.

When the nature of the leaking gas or the size of the leak constitutes a more serious hazard, self-contained breathing apparatus (for those trained and tested in its use) or protective apparel, or both, may be required. Basic action for large or uncontrolled leaks may include any of the following steps:

1. evacuation of personnel

2. rescue of injured personnel by crew equipped with adequate personal protective apparel and breathing apparatus

3. fire fighting action (only if trained to do so)

4. emergency repair

5. decontamination

Small-Scale Mercury Spill Response Procedure (also found as Appendix A-12)

Liquid mercury can vaporize and is a health hazard. A spill of mercury is challenging to clean up because the beads of spilled mercury can scatter across surfaces and fall into cracks.

What to do if there is a small-scale mercury spill such as a broken thermometer:

1. If in a classroom or occupied room, have all students and personnel who did not come in contact and were not near the mercury spill leave the room immediately without walking near the contaminated area. If there is any chance of having tracked any of the spill or contacted any vapor, they should first remove and bag their shoes and leave inside the contained area, and then leave the room. If the shoes did not come in direct contact with the mercury, they can later be aired out.

2. Contact Facilities Management to request a clean-up (768-9576). They have a mercury spill kit and one is also available in the Chemical Storage Room Folsom 103B and Folsom Room 202. Facilities will contact the UMPI Emergency and Safety Coordinator, who will then contact the Department of Environmental Protection to report the spill.

3. Block off the contaminated area with caution tape and lock and bar further entry to the area. Consider shutting off air handlers to the area to minimize the spread of vapor and consider turning on an exhaust fan or chemical hood if present to remove the vapor.

Initial clean-up

Equipment needed: Mercury Spill Kit, water, paper towels, [eyedroppers, index cards], trisodium phosphate cleaning solution, plastic bags and a large overpack container.

1. Any person entering the area for clean-up should wear booties, coverall, protective glasses and gloves. Remove any jewelry. Keep a set of clean clothes outside of the area.
2. Identify what can be cleaned and what cannot. If items cannot be cleaned, such as those with fabric, place in plastic bag, tape shut and put in large waste can.
3. Carefully pick up broken glass and beads from the broken item onto a paper towel and gently surround with the paper towel and put in a zip-lock or thick type plastic bag. Do NOT use a broom or mop or vacuum cleaner at this point to clean up the mercury beads. An index card or scoop from the spill kit can be used to help direct the waste. A flashlight can be used to detect mercury beads and an eyedropper can be used to help pick up beads. All mercury beads, broken glass, paper towels and any other contaminated items should be placed in plastic bags, sealed and placed in a larger overpack container for hazardous waste that can be tightly shut.
4. Sprinkle absorption powder from a mercury spill kit onto the floor or bench area where the spill occurred and surrounding areas where it may have spread to. The powder binds to the mercury. Rub gently into cracks and other inaccessible areas. Dampen powder with wet paper towel, then clean up area with wet paper towels. Collect all wet paper towels, put in plastic bags, seal and place in hazardous waste barrel. The activated sponge from the mercury spill kit can be used as well and capped when finished. Once all of the absorbent is cleaned up, a final scrub and wash with TSP (trisodium phosphate) can be performed. If a mop is used for this clean-up, the mop-head should be disposed of in the hazardous waste overpack container. All gloves should be taken off inside out and placed in the waste bags and overpack container.
5. Mercury indicator powder can be left overnight to identify any remaining mercury. If powder turns brown, mercury is present. Further clean-up is needed. Mercury Vapor Absorbent can be sprinkled into inaccessible areas to absorb vapors.
6. Call the Department of Environmental Protection to notify about the spill and clean-up, and to request a visit to identify if any remaining mercury vapor can be detected with their instruments.
7. All contaminated items and waste should be considered hazardous and should be disposed of by proper procedures for hazardous waste. They should be stored before pick-up in the Chemical

Storage Area and logged into the hazardous waste manifest. UMPI uses Lab Pak, Inc. to pick-up and dispose of hazardous waste.

Resources:

Lab Safety Supply Mercury Spill Kit information

New York State Department of Health information page:

https://www.health.ny.gov/environmental/chemicals/hsees/mercury/cleaning_up_a_small_mercury_spill.htm

Appendix K= Permissible Exposure Limits

https://www.osha.gov/dsg/annotated-pels/

OSHA Annotated Table Z-1[(a)]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		**Cal/OSHA PEL[(f)]** *(as of 4/26/13)*	**NIOSH REL[(g)]** *(as of 4/26/13)*	**ACGIH® 2015 TLV®[(h)]**
Substance	**CAS No.[(c)]**	**ppm[(d)]**	**mg/m³[(e)]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Acetaldehyde	75-07-0	200	360	(C) 25 ppm	Ca See Appendix A See Appendix C	(C) 25 ppm
Acetic acid	64-19-7	10	25	10 ppm (ST) 15 ppm (C) 40 ppm	10 ppm (ST) 15 ppm	10 ppm (ST) 15 ppm
Acetic anhydride	108-24-7	5	20	(C) 5 ppm	(C) 5 ppm	1 ppm (ST) 3 ppm
Acetone	67-64-1	1000	2400	500 ppm (ST) 750 ppm (C) 3000 ppm	250 ppm	250 ppm (ST) 500 ppm
Acetonitrile	75-05-8	40	70	40 ppm (ST) 60 ppm	20 ppm	20 ppm
2-Acetylaminofluorene; see 1910.1014	53-96-3			See Section 5209	Ca See Appendix A	
Acetylene dichloride; see 1,2-Dichloroethylene						
Acetylene tetrabromide	79-27-6	1	14	1 ppm	See Appendix D	0.1 ppm (IFV)
Acrolein	107-02-8	0.1	0.25	(C) 0.1 ppm	0.1 ppm (ST) 3 ppm	(C) 0.1 ppm
Acrylamide	79-06-1		0.3	0.03 mg/m³	Ca 0.03 mg/m³ See Appendix A	0.03 mg/m³(IFV)

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Acrylonitrile; see 1910.1045	107-13-1			2 ppm Section 5213	Ca 1 ppm (C) 10 ppm [15-min] See Appendix A	2 ppm
Aldrin	309-00-2		0.25	0.25 mg/m^3	Ca 0.25 mg/m^3 See Appendix A	0.05 mg/m^3(IFV)
Allyl alcohol	107-18-6	2	5	0.5 ppm (ST) 4 ppm	2 ppm (ST) 4 ppm	0.5 ppm
Allyl chloride	107-05-1	1	3	1 ppm (ST) 2 ppm	1 ppm (ST) 2 ppm	1 ppm (ST) 2 ppm
Allyl glycidyl ether (AGE)	106-92-3	(C) 10	(C) 45	0.2 ppm	5 ppm (ST) 10 ppm	1 ppm
Allyl propyl disulfide	2179-59-1	2	12	2 ppm (ST) 3 ppm	2 ppm	0.5 ppm
alpha-Alumina	1344-28-1			see PNOR	See Appendix D	See *TLV®* for Aluminum, metal and insoluble compounds
Total dust			15	10 mg/m^3		
Respirable fraction			5	5 mg/m^3		
Aluminum Metal (as Al)	7429-90-5					
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction;			5	5 mg/m^3	5 mg/m^3	1 mg/m^3

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
4-Aminodiphenyl see 1910.1011	92-67-1			See Section 5209	Ca See Appendix A	Exposure by all routes should be carefully controlled to levels as low as possible
2-Aminoethanol; see Ethanolamine						
2-Aminopyridine	504-29-0	0.5	2	0.5 ppm	0.5 ppm	0.5 ppm
Ammonia	7664-41-7	50	35	25 ppm (ST) 35 ppm	25 ppm (ST) 35 ppm	25 ppm (ST) 35 ppm
Ammonium sulfamate	7773-06-0					
Total dust			15	10 mg/m^3	10 mg/m^3	10 mg/m^3
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
n-Amyl acetate	628-63-7	100	525	50 ppm (ST) 100 ppm	100 ppm	50 ppm (ST) 100 ppm
sec-Amyl acetate	626-38-0	125	650	50 ppm (ST) 100 ppm	125 ppm	50 ppm (ST) 100 ppm
Aniline and homologs	62-53-3	5	19	2 ppm (aniline only)	Ca See Appendix A	2 ppm (aniline only)
Anisidine (o-,p-isomers)	29191-52-4		0.5	0.5 mg/m^3	Ca 0.5 mg/m^3 See Appendix A	0.5 mg/m^3
Antimony and compounds (as Sb)	7440-36-0		0.5	0.5 mg/m^3	0.5 mg/m^3	0.5 mg/m^3

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
ANTU (alpha Naphthylthiourea)	86-88-4		0.3	0.3 mg/m^3	0.3 mg/m^3	0.3 mg/m^3
Arsenic, inorganic compounds (as As) see 1910.1018	7440-38-2			0.01 mg/m^3 See Section 5214	Ca (C) 0.002 mg/m^3[15-min] See Appendix A	0.01 mg/m^3
Arsenic, organic compounds (as As)	7440-38-2		0.5	0.2 mg/m^3	None	
Arsine	7784-42-1	0.05	0.2	0.05 ppm	Ca 0.002 mg/m^3[15-min] See Appendix A	0.005 ppm
Asbestos; see 1910.1001	Varies with compound			See Section 5208	Ca 0.1 f/cm^3 See Appendix A See Appendix C	0.1 f/cc (resp. fiber)
Azinphos-methyl	86-50-0		0.2	0.2 mg/m^3	0.2 mg/m^3	0.2 mg/m^3(IFV)
Barium, soluble compounds (as Ba)	7440-39-3		0.5	0.5 mg/m^3	0.5 mg/m^3	0.5 mg/m^3
Barium sulfate	7727-43-7			see PNOR		
Total dust			15	10 mg/m^3	10 mg/m^3	5 mg/m^3 (no asbestos and < 1% crystalline silica)
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Benomyl	17804-35-2				See Appendix D	1 mg/m^3 (IHL)

OSHA Annotated Table Z-1[(a)]

*Go to list of all footnotes

Substance	CAS No.[(c)]	Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		Cal/OSHA PEL[(f)] *(as of 4/26/13)*	NIOSH REL[(g)] *(as of 4/26/13)*	ACGIH®2015 TLV®[(h)]
		ppm[(d)]	mg/m³[(e)]	8-hour TWA (ST) STEL (C) Ceiling	Up to 10-hour TWA (ST) STEL (C) Ceiling	8-hour TWA (ST) STEL (C) Ceiling
Total dust			15	10 mg/m³		
Respirable fraction			5	5 mg/m³		
Benzene; See 1910.1028; See Table Z-2 for the limits applicable in the operations or sectors excluded in 1910.1028[(j)]	71-43-2			1 ppm (ST) 5 ppm See Section 5218	Ca 0.1 ppm (ST) 1 ppm See Appendix A	0.5 ppm (ST) 2.5 ppm
Benzidine; See 1910.1010	92-87-5			See Section 5209	Ca See Appendix A See Appendix C	Exposure by all routes should be carefully controlled to levels as low as possible
p-Benzoquinone; see Quinone						
Benzo(a)pyrene; see Coal tar pitch volatiles						
Benzoyl peroxide	94-36-0		5	5 mg/m³	5 mg/m³	5 mg/m³
Benzyl chloride	100-44-7	1	5	1 ppm	(C) 1 ppm [15 min]	1 ppm
Beryllium and beryllium compounds (as Be)	7440-41-7	See Annotated Z-2		See Annotated Z-2		
Biphenyl; see Diphenyl						
Bismuth telluride, Undoped	1304-82-1					
Total dust			15	10 mg/m³	10 mg/m³	10 mg/m³
Respirable fraction			5	5 mg/m³	5 mg/m³	
Boron oxide	1303-86-2					

OSHA Annotated Table Z-1[(a)]

[*Go to list of all footnotes]

Substance	CAS No.[(c)]	Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		Cal/OSHA PEL[(f)] *(as of 4/26/13)*	NIOSH REL[(g)] *(as of 4/26/13)*	ACGIH® 2015 TLV®[(h)]
Substance	**CAS No.[(c)]**	**ppm[(d)]**	**mg/m³[(e)]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Total dust			15	10 mg/m³	10 mg/m³	10 mg/m³
Boron trifluoride	7637-07-2	(C) 1	(C) 3	(C) 1 ppm	(C) 1 ppm	(C) 1 ppm
Bromine	7726-95-6	0.1	0.7	(C) 0.1 ppm	0.1 ppm (ST) 0.3 ppm	0.1 ppm (ST) 0.2 ppm
Bromoform	75-25-2	0.5	5	0.5 ppm	0.5 ppm	0.5 ppm
Butadiene (1,3-Butadiene); See 29 CFR 1910.1051; 29 CFR 1910.19(l)	106-99-0	1 ppm / 5 ppm STEL		1 ppm (ST) 5 ppm See Section 5201	Ca See Appendix A	2 ppm
Butanethiol; see Butyl mercaptan						
2-Butanone (Methyl ethyl ketone)	78-93-3	200	590	200 ppm (ST) 300 ppm	200 ppm (ST) 300 ppm	200 ppm (ST) 300 ppm
2-Butoxyethanol	111-76-2	50	240	20 ppm	5 ppm	20 ppm
n-Butyl-acetate	123-86-4	150	710	150 ppm (ST) 200 ppm	150 ppm (ST) 200 ppm	150 ppm (ST) 200 ppm
sec-Butyl acetate	105-46-4	200	950	200 ppm	200 ppm	200 ppm
tert-Butyl-acetate	540-88-5	200	950	200 ppm	200 ppm	200 ppm
n-Butyl alcohol	71-36-3	100	300	(C) 50 ppm	(C) 50 ppm	20 ppm
sec-Butyl alcohol	78-92-2	150	450	100 ppm	100 ppm (ST) 150 ppm	100 ppm
tert-Butyl alcohol	75-65-0	100	300	100 ppm	100 ppm	100 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
				(ST) 150 ppm	(ST) 150 ppm	
Butylamine	109-73-9	(C) 5	(C) 15	(C) 5 ppm	(C) 5 ppm	(C) 5 ppm
tert-Butyl chromate (as CrO_3)[m]; see 1910.1026	1189-85-1			(C) 0.1 mg/m^3	Ca 0.001 mg/m^3 CR (VI) See Appendix A See Appendix C	(C) 0.1 mg/m^3
n-Butyl glycidyl ether (BGE)	2426-08-6	50	270	25 ppm	(C) 5.6 ppm [15-min]	3 ppm
Butyl mercaptan	109-79-5	10	35	0.5 ppm	(C) 0.5 ppm [15-min]	0.5 ppm
p-tert-Butyltoluene	98-51-1	10	60	1 ppm (ST) 20 ppm	10 ppm (ST) 20 ppm	1 ppm
Cadmium (as Cd); see 1910.1027	7440-43-9			0.005 mg/m^3 see Sections 1532 & 5207	Ca See Appendix A	0.01 mg/m^3 (total) 0.002 mg/m^3 (resp.)
Calcium Carbonate	1317-65-3			see PNOR		See *TLV®book* Appendix G
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Calcium hydroxide	1305-62-0					
Total dust			15	5 mg/m^3	5 mg/m^3	5 mg/m^3
Respirable fraction			5			

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Calcium oxide	1305-78-8		5	2 mg/m^3	2 mg/m^3	2 mg/m^3
Calcium silicate	1344-95-2			see PNOR		
Total dust			15	10 mg/m^3	10 mg/m^3	10 mg/m^3, synthetic non-fibrous (no asbestos and < 1% crystalline silica)
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Calcium sulfate	7778-18-9			see PNOR		10 mg/m^3(IHL)
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Camphor, synthetic	76-22-2		2	2 mg/m^3	2 mg/m^3	2 ppm (ST) 3 ppm
Carbaryl (Sevin)	63-25-2		5	5 mg/m^3	5 mg/m^3	0.5 mg/m^3(IFV)
Carbon black	1333-86-4		3.5	3.5 mg/m^3	3.5 mg/m^3(without PAHs); when PAHs are present, NIOSH considers carbon black to be a potential occupational carcinogen. See Appendix A,See Appendix C	3 mg/m^3 (IHL)
Carbon dioxide	124-38-9	5000	9000	5000 ppm (ST) 30,000 ppm	5000 ppm (ST) 30,000 ppm	5000 ppm (ST) 30,000 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Carbon disulfide	75-15-0	See Annotated Z-2		See Annotated Z-2		
Carbon monoxide	630-08-0	50	55	25 ppm (C) 200 ppm	35 ppm (C) 200 ppm	25 ppm
Carbon tetrachloride	56-23-5	See Annotated Z-2		See Annotated Z-2		
Cellulose	9004-34-6			see PNOR		
Total dust			15	10 mg/m^3	10 mg/m^3	10 mg/m^3
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Chlordane	57-74-9		0.5	0.5 mg/m^3	Ca 0.5 mg/m^3 See Appendix A	0.5 mg/m^3
Chlorinated camphene	8001-35-2		0.5	0.5 mg/m^3 (ST) 1 mg/m^3	Ca See Appendix A	0.5 mg/m^3 (ST) 1 mg/m^3
Chlorinated diphenyl oxide	55720-99-5		0.5	0.5 mg/m^3	0.5 mg/m^3	0.5 mg/m^3(ortho isomer)
Chlorine	7782-50-5	(C) 1	(C) 3	0.5 ppm (ST) 1 ppm	(C) 0.5 ppm [15-min]	0.5 ppm (ST) 1 ppm
Chlorine dioxide	10049-04-4	0.1	0.3	0.1 ppm (ST) 0.3 ppm	0.1 ppm (ST) 0.3 ppm	0.1 ppm (ST) 0.3 ppm
Chlorine trifluoride	7790-91-2	(C) 0.1	(C) 0.4	(C) 0.1 ppm	(C) 0.1 ppm	(C) 0.1 ppm
Chloroacetaldehyde	107-20-0	(C) 1	(C) 3	(C) 1 ppm	(C) 1 ppm	(C) 1 ppm
a-Chloroacetophenone (Phenacyl chloride)	532-27-4	0.05	0.3	0.05 ppm	0.05 ppm	0.05 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Chlorobenzene	108-90-7	75	350	10 ppm	See Appendix D	10 ppm
o-Chlorobenzylidene malononitrile	2698-41-1	0.05	0.4	(C) 0.05 ppm	(C) 0.05 ppm	(C) 0.05 ppm
Chlorobromomethane	74-97-5	200	1050	200 ppm	200 ppm	200 ppm
2-Chloro-1,3-butadiene; See beta-Chloroprene						
Chlorodiphenyl (42% Chlorine) (PCB)	53469-21-9		1	1 mg/m^3	Ca 0.001 mg/m^3 See Appendix A	1 mg/m^3
Chlorodiphenyl (54% Chlorine) (PCB)	11097-69-1		0.5	0.5 mg/m^3	Ca 0.001 mg/m^3 See Appendix A	0.5 mg/m^3
1-Chloro-2,3-epoxypropane; See Epichlorohydrin						
2-Chloroethanol; See Ethylene chlorohydrin						
Chloroethylene; see Vinyl chloride						
Chloroform (Trichloromethane)	67-66-3	(C) 50	(C) 240	2 ppm	Ca (ST) 2 ppm [60-min] See Appendix A	10 ppm
bis(Chloromethyl) ether; see 1910.1008	542-88-1			0.001 ppm See Section 5209	Ca See Appendix A	0.001 ppm
Chloromethyl methyl ether	107-30-2			See Section 5209	Ca	Exposure by all routes

OSHA Annotated Table Z-1[(a)]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		Cal/OSHA PEL[(f)] *(as of 4/26/13)*	NIOSH REL[(g)] *(as of 4/26/13)*	ACGIH®2015 TLV®[(h)]
Substance	**CAS No.**[(c)]	**ppm**[(d)]	**mg/m**^{3}[(e)]	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
see 1910.1006					See Appendix A	should be carefully controlled to levels as low as possible.
1-Chloro-1-nitropropane	600-25-9	20	100	2 ppm	2 ppm	2 ppm
Chloropicrin	76-06-2	0.1	0.7	0.1 ppm	0.1 ppm	0.1 ppm
beta-Chloroprene	126-99-8	25	90	10 ppm	Ca (C) 1 ppm [15-min] See Appendix A	10 ppm
2-Chloro-6-(trichloromethyl)pyridine	1929-82-4					
Total dust			15	10 mg/m^3	10 mg/m^3 (ST) 20 mg/m^3	10 mg/m^3 (ST) 20 mg/m^3
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Chromium (II) compounds (as Cr)	7440-47-3		0.5	0.5 mg/m^3	0.5 mg/m^3 See Appendix C	
Chromium (III) compounds (as Cr)	7440-47-3		0.5	0.5 mg/m^3	0.5 mg/m^3 See Appendix C	0.5 mg/m^3
Chromium (VI) compounds See 1910.1026[(k)]				0.005 mg/m^{3}as Cr (C) 0.1 mg/m^3 See Sections 1532.2, 5206, and 8359	Ca 0.001 mg/m^3 See Appendix A See Appendix C	0.05 mg/m^3, water soluable (includes chromic acid and chromates)
Chromium metal and insol. salts (as Cr)	7440-47-3		1	0.5 mg/m^3	0.5 mg/m^3 See Appendix C	0.01 mg/m^3, CrVI, insoluble

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Chrysene; see Coal tarpitch volatiles						Exposure by all routes should be carefully controlled to levels as low as possible.
Clopidol	2971-90-6					3 mg/m^3 (IFV)
Total dust			15	10 mg/m^3	10 mg/m^3 (ST) 20 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Coal dust (less than 5% SiO$_2$, respirable fraction)		See Annotated Z-3		See Annotated Z-3		
Coal dust (greater than or equal to 5% SiO$_2$ respirable fraction)		See Annotated Z-3		See Annotated Z-3		
Coal tar pitch volatiles (benzene soluble fraction), anthracene, BaP, phenanthrene, acridine, chrysene, pyrene)	65966-93-2		0.2	0.2 mg/m^3	Ca 0.1 mg/m^3(cyclohexane-extractable fraction) See Appendix A See Appendix C	0.2 mg/m^3(as benzene soluble aerosol)
Cobalt metal, dust, and fume (as Co)	7440-48-4		0.1	0.02 mg/m^3	0.05 mg/m^3	0.02 mg/m^3
Coke oven emissions; see 1910.1029				0.15 mg/m^3 See Section 5211	Ca 0.2 mg/m^3(benzene-soluble fraction) See Appendix A See Appendix C	
Copper	7440-50-8					

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		Cal/OSHA PEL[f] *(as of 4/26/13)*	NIOSH REL[g] *(as of 4/26/13)*	ACGIH®2015 TLV®[h]
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Fume (as Cu)			0.1	0.1 mg/m^3	0.1 mg/m^3	0.2 mg/m^3
Dusts and mists (as Cu)			1	1 mg/m^3	1 mg/m^3	1 mg/m^3
Cotton dust[l], see 1910.1043			1	1 mg/m^3 (in waste processing) See Section 5190	< 0.200 mg/m^3 See Appendix C	0.1 mg/m^3(Thor.) (raw untreated)
Crag herbicide (Sesone)	136-78-7					
Total dust			15	10 mg/m^3	10 mg/m^3	10 mg/m^3
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Cresol, all isomers	1319-77-3	5	22	5 ppm	2.3 ppm	20 mg/m^3(IFV)
Crotonaldehyde	123-73-9 / 4170-30-3	2	6	(C) 0.3 ppm	2 ppm See Appendix C (Aldehydes)	(C) 0.3 ppm
Cumene	98-82-8	50	245	50 ppm	50 ppm	50 ppm
Cyanides (as CN)	Varies with compound		5	5 mg/m^3	(C) 5 mg/m^3[10-min]	(C) 5 mg/m^3, salts
Cyclohexane	110-82-7	300	1050	300 ppm	300 ppm	100 ppm
Cyclohexanol	108-93-0	50	200	50 ppm	50 ppm	50 ppm
Cyclohexanone	108-94-1	50	200	25 ppm	25 ppm	20 ppm (ST) 50 ppm
Cyclohexene	110-83-8	300	1015	300 ppm	300 ppm	300 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Cyclopentadiene	542-92-7	75	200	75 ppm	75 ppm	75 ppm
2,4-D (Dichlorophen-oxyacetic acid)	94-75-7		10	10 mg/m^3	10 mg/m^3	10 mg/m^3(IHL)
Decaborane	17702-41-9	0.05	0.3	0.05 ppm (ST) 0.15 ppm	0.05 ppm (ST) 0.15 ppm	0.05 ppm (ST) 0.15 ppm
Demeton (Systox)	8065-48-3		0.1	0.1 mg/m^3	0.1 mg/m^3	0.05 mg/m^3(IFV)
Diacetone alcohol (4-Hydroxy-4-methyl-2-pentanone)	123-42-2	50	240	50 ppm	50 ppm	50 ppm
1,2-Diaminoethane; see Ethylenediamine						
Diazomethane	334-88-3	0.2	0.4	0.2 ppm	0.2 ppm	0.2 ppm
Diborane	19287-45-7	0.1	0.1	0.1 ppm	0.1 ppm	0.1 ppm
1,2-Dibromo-3-chloropropane (DBCP); see 1910.1044	96-12-8			0.001 ppm See Section 5212	Ca See Appendix A	
1,2-Dibromoethane; see Ethylene dibromide						
Dibutyl phosphate	107-66-4	1	5	1 ppm (ST) 2 ppm	1 ppm (ST) 2 ppm	5 mg/m^3 (IFV)
Dibutyl phthalate	84-74-2		5	5 mg/m^3	5 mg/m^3	5 mg/m^3
o-Dichlorobenzene	95-50-1	(C) 50	(C) 300	25 ppm (C) 50 ppm	(C) 50 ppm	25 ppm (C) 50 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH® 2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
p-Dichlorobenzene	106-46-7	75	450	10 ppm (ST) 110 ppm (C) 200 ppm	Ca See Appendix A	10 ppm
3,3'-Dichlorobenzidine; see 1910.1007	91-94-1			See Section 5209	Ca See Appendix A	Exposure by all routes should be carefully controlled to levels as low as possible.
Dichlorodifluoromethane	75-71-8	1000	4950	1000 ppm (C) 6200 ppm	1000 ppm	1000 ppm
1,3-Dichloro-5,5-dimethyl hydantoin	118-52-5		0.2	0.2 mg/m^3 (ST) 0.4 mg/m^3	0.2 mg/m^3 (ST) 0.4 mg/m^3	0.2 mg/m^3 (ST) 0.4 mg/m^3
Dichlorodiphenyltrichloroethane (DDT)	50-29-3		1	1 mg/m^3	Ca 0.5 mg/m^3 See Appendix A	1 mg/m^3
1,1-Dichloroethane	75-34-3	100	400	100 ppm	100 ppm See Appendix C (Chloroethanes)	100 ppm
1,2-Dichloroethane; see Ethylene dichloride						
1,2-Dichloroethylene	540-59-0	200	790	200 ppm	200 ppm	200 ppm
Dichloroethyl ether	111-44-4	(C) 15	(C) 90	5 ppm (ST) 10 ppm	Ca 5 ppm (ST) 10 ppm See Appendix A	5 ppm (ST) 10 ppm
Dichloromethane; see Methylene chloride						

OSHA Annotated Table Z-1[(a)]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		Cal/OSHA PEL[(f)] *(as of 4/26/13)*	NIOSH REL[(g)] *(as of 4/26/13)*	ACGIH® 2015 TLV®[(h)]
Substance	**CAS No.[(c)]**	**ppm[(d)]**	**mg/m^3[(e)]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Dichloromono fluoromethane	75-43-4	1000	4200	10 ppm	10 ppm	10 ppm
1,1-Dichloro-1-nitroethane	594-72-9	(C) 10	(C) 60	2 ppm	2 ppm	2 ppm
1,2-Dichloropropane; see Propylene dichloride						
Dichlorotetrafluoroethane	76-14-2	1000	7000	1000 ppm	1000 ppm	1000 ppm
Dichlorvos (DDVP)	62-73-7		1	1 mg/m^3	1 mg/m^3	0.1 mg/m^3(IFV)
Dicyclopentadienyl iron	102-54-5					
Total dust			15	10 mg/m^3	10 mg/m^3	10 mg/m^3 as Fe
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Dieldrin	60-57-1		0.25	0.25 mg/m^3	Ca 0.25 mg/m^3 See Appendix A	0.1 mg/m^3(IFV)
Diethylamine	109-89-7	25	75	(C) 5 ppm	10 ppm (ST) 25 ppm	5 ppm (ST) 15 ppm
2-Diethylaminoethanol	100-37-8	10	50	2 ppm	10 ppm	2 ppm
Diethyl ether; see Ethyl ether						
Difluorodibromomethane	75-61-6	100	860	100 ppm	100 ppm	100 ppm
Diglycidyl ether (DGE)	2238-07-5	(C) 0.5	(C) 2.8	0.1 ppm	Ca 0.1 ppm See Appendix A	0.01 ppm
Dihydroxybenzene; see						

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		Cal/OSHA PEL[f] *(as of 4/26/13)*	NIOSH REL[g] *(as of 4/26/13)*	ACGIH®2015 TLV®[h]
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Hydroquinone						
Diisobutyl ketone	108-83-8	50	290	25 ppm	25 ppm	25 ppm
Diisopropylamine	108-18-9	5	20	5 ppm	5 ppm	5 ppm
4-Dimethylaminoazo-benzene; see 1910.1015	60-11-7			See Section 5209	Ca See Appendix A	
Dimethoxymethane; see Methylal						
Dimethyl acetamide	127-19-5	10	35	10 ppm	10 ppm	10 ppm
Dimethylamine	124-40-3	10	18	5 ppm (ST) 15 ppm	10 ppm	5 ppm (ST) 15 ppm
Dimethylaminobenzene; see Xylidine						
Dimethylaniline (N,N-Dimethylaniline)	121-69-7	5	25	5 ppm (ST) 10 ppm	5 ppm (ST) 10 ppm	5 ppm (ST) 10 ppm
Dimethylbenzene; see Xylene						
Dimethyl-1,2-dibromo-2,2-dichloroethylphosphate	300-76-5		3	3 mg/m^3	3 mg/m^3	0.1 mg/m^3(IFV)
Dimethylformamide	68-12-2	10	30	10 ppm	10 ppm	10 ppm
2,6-Dimethyl-4-heptanone; see Diisobutyl ketone						
1,1-Dimethylhydrazine	57-14-7	0.5	1	0.01 ppm	Ca (C) 0.06 ppm [2-hr]	0.01 ppm

OSHA Annotated Table Z-1[(a)]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		**Cal/OSHA PEL[(f)]** *(as of 4/26/13)*	**NIOSH REL[(g)]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[(h)]**
Substance	**CAS No.[(c)]**	**ppm[(d)]**	**mg/m³[(e)]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
					See Appendix A	
Dimethylphthalate	131-11-3		5	5 mg/m³	5 mg/m³	5 mg/m³
Dimethyl sulfate	77-78-1	1	5	0.1 ppm	Ca 0.1 ppm See Appendix A	0.1 ppm
Dinitrobenzene (all isomers)			1	0.15 ppm	1 mg/m³	0.15 ppm
(ortho)	528-29-0					
(meta)	99-65-0					
(para)	100-25-4					
Dinitro-o-cresol	534-52-1		0.2	0.2 mg/m³	0.2 mg/m³	0.2 mg/m³
Dinitrotoluene	25321-14-6		1.5	0.15 mg/m³	Ca 1.5 mg/m³ See Appendix A	0.2 mg/m³
Dioxane (Diethylene dioxide)	123-91-1	100	360	0.28 ppm	Ca (C) 1 ppm [30-min] See Appendix A	20 ppm
Diphenyl (Biphenyl)	92-52-4	0.2	1	0.2 ppm	0.2 ppm	0.2 ppm
Diphenylmethane diisocyanate; see Methylene bisphenylisocyanate						
Dipropylene glycol methyl ether	34590-94-8	100	600	100 ppm (ST) 150 ppm	100 ppm (ST) 150 ppm	100 ppm (ST) 150 ppm

OSHA Annotated Table Z-1[(a)]

[*Go to list of all footnotes](#)

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		**Cal/OSHA PEL[(f)]** *(as of 4/26/13)*	**NIOSH REL[(g)]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[(h)]**
Substance	**CAS No.[(c)]**	**ppm[(d)]**	**mg/m^3[(e)]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Di-sec octyl phthalate (Di-(2-ethylhexyl) phthalate)	117-81-7		5	5 mg/m^3	Ca 5 mg/m^3 (ST) 10 mg/m^3 See Appendix A	5 mg/m^3
Emery	12415-34-8			see PNOR	See Appendix D	See *TLV®* for Aluminum metal and insoluble compounds
Total dust			15	10 mg/m^3		
Respirable fraction			5	5 mg/m^3		
Endrin	72-20-8		0.1	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
Epichlorohydrin	106-89-8	5	19	0.05 ppm	Ca See Appendix A	0.5 ppm
EPN	2104-64-5		0.5	0.1 mg/m^3	0.5 mg/m^3	0.1 mg/m^3(IHL)
1,2-Epoxypropane; see Propylene oxide						
2,3-Epoxy-1-propanol; see Glycidol						
Ethanethiol; see Ethyl mercaptan						
Ethanolamine	141-43-5	3	6	3 ppm (ST) 6 ppm	3 ppm (ST) 6 ppm	3 ppm (ST) 6 ppm
2-Ethoxyethanol (Cellosolve)	110-80-5	200	740	5 ppm	0.5 ppm	5 ppm
2-Ethoxyethyl acetate	111-15-9	100	540	5 ppm	0.5 ppm	5 ppm

OSHA Annotated Table Z-1[(a)]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		Cal/OSHA PEL[(f)] *(as of 4/26/13)*	NIOSH REL[(g)] *(as of 4/26/13)*	ACGIH®2015 TLV®[(h)]
Substance	**CAS No.**[(c)]	**ppm**[(d)]	**mg/m³**[(e)]	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
(Cellosolve acetate)						
Ethyl acetate	141-78-6	400	1400	400 ppm	400 ppm	400 ppm
Ethyl acrylate	140-88-5	25	100	5 ppm (ST) 25 ppm	Ca See Appendix A	5 ppm (ST) 15 ppm
Ethyl alcohol (Ethanol)	64-17-5	1000	1900	1000 ppm	1000 ppm	(ST) 1000 ppm
Ethylamine	75-04-7	10	18	(C) 5 ppm	10 ppm	5 ppm (ST) 15 ppm
Ethyl amyl ketone (5-Methyl-3-heptanone)	541-85-5	25	130	25 ppm	25 ppm	10 ppm
Ethyl benzene	100-41-4	100	435	100 ppm (ST) 125 ppm	100 ppm (ST) 125 ppm	20 ppm
Ethyl bromide	74-96-4	200	890	5 ppm	See Appendix D	5 ppm
Ethyl butyl ketone (3-Heptanone)	106-35-4	50	230	50 ppm (ST) 75 ppm	50 ppm	50 ppm (ST) 75 ppm
Ethyl chloride	75-00-3	1000	2600	100 ppm	See Appendix C(Chloroethanes)	100 ppm
Ethyl ether	60-29-7	400	1200	400 ppm (ST) 500 ppm	See Appendix D	400 ppm (ST) 500 ppm
Ethyl formate	109-94-4	100	300	100 ppm	100 ppm	(ST) 100 ppm
Ethyl mercaptan	75-08-1	(C) 10	(C) 25	0.5 ppm	(C) 0.5 ppm [15-min]	0.5 ppm
Ethyl silicate	78-10-4	100	850	10 ppm	10 ppm	10 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Ethylene chlorohydrin	107-07-3	5	16	(C) 1 ppm	(C) 1 ppm	(C) 1 ppm
Ethylenediamine	107-15-3	10	25	10 ppm	10 ppm	10 ppm
Ethylene dibromide	106-93-4	See Annotated Z-2		See Annotated Z-2		
Ethylene dichloride (1,2-Dichloroethane)	107-06-2	See Annotated Z-2		See Annotated Z-2		
Ethylene glycol dinitrate	628-96-6	(C) 0.2	(C) 1	0.05 ppm for exposures to mixture of ethylene glycol dinitrate and nitroglycerin	(ST) 0.1 mg/m^3	0.05 ppm
Ethylene glycol methylacetate; see Methylcellosolve acetate						
Ethyleneimine; see 1910.1012	151-56-4			0.5 ppm See Section 5209	Ca See Appendix A	0.05 ppm (ST) 0.1 ppm
Ethylene oxide; see 1910.1047	75-21-8			1 ppm (ST) 5 ppm See Section 5220	Ca < 0.1 ppm (C) 5 ppm [10-min/day] See Appendix A	1 ppm
Ethylidene chloride; see 1,1-Dichlorethane						
N-Ethylmorpholine	100-74-3	20	94	5 ppm	5 ppm	5 ppm
Ferbam	14484-64-1					

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Total dust		....	15	10 mg/m^3	10 mg/m^3	5 mg/m^3 (IHL)
Ferrovanadium dust	12604-58-9	....	1	1 mg/m^3 (ST) 3 mg/m^3	1 mg/m^3 (ST) 3 mg/m^3	1 mg/m^3 (ST) 3 mg/m^3
Fluorides (as F)	Varies with compound	....	2.5	2.5 mg/m^3	2.5 mg/m^3	2.5 mg/m^3
Fluorine	7782-41-4	0.1	0.2	0.1 ppm	0.1 ppm	1 ppm (ST) 2 ppm
Fluorotrichloromethane (Trichlorofluoromethane)	75-69-4	1000	5600	(C) 1000 ppm	(C) 1000 ppm	(C) 1000 ppm
Formaldehyde; see 1910.1048	50-00-0			0.75 ppm (ST) 2 ppm See Section 5217	Ca 0.016 ppm (C) 0.1 ppm [15-min] See Appendix A	(C) 0.3 ppm
Formic acid	64-18-6	5	9	5 ppm (ST) 10 ppm	5 ppm	5 ppm (ST) 10 ppm
Furfural	98-01-1	5	20	2 ppm	See Appendix D	2 ppm
Furfuryl alcohol	98-00-0	50	200	10 ppm (ST) 15 ppm	10 ppm (ST) 15 ppm	10 ppm (ST) 15 ppm
Grain dust (oat, wheat barley)			10	10 mg/m^3	4 mg/m^3	4 mg/m^3
Glycerin (mist)	56-81-5			PNOR	See Appendix D	
Total dust			15	10 mg/m^3		

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Respirable fraction			5	5 mg/m^3		
Glycidol	556-52-5	50	150	2 ppm	25 ppm	2 ppm
Glycol monoethyl ether; see 2-Ethoxyethanol						
Graphite, natural respirable dust	7782-42-5	See Annotated Z-3		See Annotated Z-3		
Graphite, synthetic						
Total dust			15	10 mg/m^3	See Appendix D	
Respirable Fraction			5	5 mg/m^3		2 mg/m^3 (all forms except fibers)
Guthion; see Azinphos methyl						
Gypsum	13397-24-5			PNOR		See calcium sulfate
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Hafnium	7440-58-6		0.5	0.5 mg/m^3	0.5 mg/m^3	0.5 mg/m^3
Heptachlor	76-44-8		0.5	0.05 mg/m^3	Ca 0.5 mg/m^3 See Appendix A	0.05 mg/m^3
Heptane (n-Heptane)	142-82-5	500	2000	400 ppm (ST) 500 ppm	85 ppm (ST) 440 ppm [15-min]	400 ppm (ST) 500 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Hexachloroethane	67-72-1	1	10	1 ppm	Ca 1 ppm See Appendix A See Appendix C (Chloroethanes)	1 ppm
Hexachloronaphthalene	1335-87-1		0.2	0.2 mg/m^3	0.2 mg/m^3	0.2 mg/m^3
n-Hexane	110-54-3	500	1800	50 ppm	50 ppm	50 ppm
2-Hexanone (Methyl n-butyl ketone)	591-78-6	100	410	1 ppm (ST) 10 ppm	1 ppm	5 ppm (ST) 10 ppm
Hexone (Methyl isobutyl ketone)	108-10-1	100	410	50 ppm (ST) 75 ppm	50 ppm (ST) 75 ppm	20 ppm (ST) 75 ppm
sec-Hexyl acetate	108-84-9	50	300	50 ppm	50 ppm	50 ppm
Hydrazine	302-01-2	1	1.3	0.01 ppm	Ca (C) 0.03 ppm [2-hr] See Appendix A	0.01 ppm
Hydrogen bromide	10035-10-6	3	10	(C) 3 ppm	(C) 3 ppm	(C) 2 ppm
Hydrogen chloride	7647-01-0	(C) 5	(C) 7	(C) 5 ppm	(C) 5 ppm	(C) 2 ppm
Hydrogen cyanide	74-90-8	10	11	(C) 4.7 ppm	(ST) 4.7 ppm	(C) 4.7 ppm
Hydrogen fluoride (as F)	7664-39-3	See Annotated Z-2		See Annotated Z-2		
Hydrogen peroxide	7722-84-1	1	1.4	1 ppm	1 ppm	1 ppm
Hydrogen selenide (as Se)	7783-07-5	0.05	0.2	0.05 ppm	0.05 ppm	0.05 ppm

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Hydrogen sulfide	7783-06-4	See Annotated Z-2		See Annotated Z-2		
Hydroquinone	123-31-9	....	2	2 mg/m^3	(C) 2 mg/m^3[15-min]	1 mg/m^3
Iodine	7553-56-2	(C) 0.1	(C) 1	(C) 0.1 ppm	(C) 0.1 ppm	0.01 ppm (IFV) (ST) 0.1 ppm (V)
Iron oxide	1309-37-1		10 (fume)	5 mg/m^3(fume)	5 mg/m^3 (dust and fume)	5 mg/m^3(resp.)
Isomyl acetate	123-92-2	100	525	50 ppm (ST) 100 ppm	100 ppm	50 ppm (ST) 100 ppm
Isomyl alcohol (primary and secondary)	123-51-3	100	360	100 ppm (ST) 125 ppm	100 ppm (ST) 125 ppm	100 ppm (ST) 125 ppm
Isobutyl acetate	110-19-0	150	700	150 ppm	150 ppm	150 ppm
Isobutyl alcohol	78-83-1	100	300	50 ppm	50 ppm	50 ppm
Isophorone	78-59-1	25	140	4 ppm	4 ppm	(C) 5 ppm
Isopropyl acetate	108-21-4	250	950	250 ppm (ST) 310 ppm	See Appendix D	100 ppm (ST) 200 ppm
Isopropyl alcohol	67-63-0	400	980	400 ppm (ST) 500 ppm	400 ppm (ST) 500 ppm	200 ppm (ST) 400 ppm
Isopropylamine	75-31-0	5	12	5 ppm (ST) 10 ppm	See Appendix D	5 ppm (ST) 10 ppm
Isopropyl ether	108-20-3	500	2100	250 ppm	500 ppm	250 ppm (ST) 310 ppm
Isopropyl glycidyl ether (IGE)	4016-14-2	50	240	50 ppm	(C) 50 ppm [15-min]	50 ppm

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		Cal/OSHA PEL[f] *(as of 4/26/13)*	NIOSH REL[g] *(as of 4/26/13)*	ACGIH® 2015 TLV®[h]
Substance	**CAS No.**[c]	**ppm**[d]	**mg/m³**[e]	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
				(ST) 75 ppm		(ST) 75 ppm
Kaolin	1332-58-7					
Total dust			15		10 mg/m³	
Respirable fraction			5	2 mg/m³ (no asbestos, < 1% crystalline silica)	5 mg/m³	2 mg/m³ (no asbestos and < 1% crystalline silica)
Ketene	463-51-4	0.5	0.9	0.5 ppm (ST) 1.5 ppm	0.5 ppm (ST) 1.5 ppm	0.5 ppm (ST) 1.5 ppm
Lead inorganic (as Pb); see 1910.1025	7439-92-1			0.05 mg/m³ See Section 5198	0.05 mg/m³ See Appendix C	0.05 mg/m³
Limestone	1317-65-3			see PNOR		See calcium carbonate
Total dust			15	10 mg/m³	10 mg/m³	
Respirable fraction			5	5 mg/m³	5 mg/m³	
Lindane	58-89-9		0.5	0.5 mg/m³	0.5 mg/m³	0.5 mg/m³
Lithium hydride	7580-67-8		0.025	0.025 mg/m³	0.025 mg/m³	(C) 0.05 mg/m³ (IHL)
L.P.G. (Liquified petroleum gas)	68476-85-7	1000	1800	1000 ppm	1000 ppm	See *TLV®book* Appendix F
Magnesite	546-93-0			See PNOR		See *TLV®book* Appendix G
Total dust			15	10 mg/m³	10 mg/m³	

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Magnesium oxide fume - Total Particulate	1309-48-4		15	10 mg/m^3	See Appendix D	10 mg/m^3(IHL)
Malathion - Total dust	121-75-5		15	10 mg/m^3	10 mg/m^3	1 mg/m^3 (IFV)
Maleic anhydride	108-31-6	0.25	1	0.1 ppm	1 mg/m^3	0.01 mg/m^3(IFV)
Manganese compounds (as Mn)	7439-96-5		(C) 5	0.2 mg/m^3	1 mg/m^3 (ST) 3 mg/m^3	0.02 mg/m^3(resp.) 0.1 mg/m^3(IHL) (for elemental and inorganic compounds)
Manganese fume (as Mn)	7439-96-5		(C) 5	0.2 mg/m^3	1 mg/m^3 (ST) 3 mg/m^3	0.02 mg/m^3(resp.) 0.1 mg/m^3(IHL) (for elemental and inorganic compounds)
Marble	1317-65-3			See PNOR		
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Mercury (aryl and inorganic) (as Hg)	7439-97-6	See Annotated Z-2		See Annotated Z-2		
Mercury (organo) alkylcompounds (as Hg)	7439-97-6	See Annotated Z-2		See Annotated Z-2		
Mercury (vapor) (as Hg)	7439-97-6	See Annotated Z-2		See Annotated Z-2		
Mesityl oxide	141-79-7	25	100	15 ppm (ST) 25 ppm	10 ppm	15 ppm (ST) 25 ppm

OSHA Annotated Table Z-1[(a)]

[*Go to list of all footnotes]

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		**Cal/OSHA PEL[(f)]** *(as of 4/26/13)*	**NIOSH REL[(g)]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[(h)]**
Substance	**CAS No.[(c)]**	**ppm[(d)]**	**mg/m^3[(e)]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Methanethiol; see Methyl mercaptan						
Methoxychlor - Total dust	72-43-5		15	10 mg/m^3	Ca See Appendix A	10 mg/m^3
2-Methoxyethanol; (Methyl cellosolve)	109-86-4	25	80	5 ppm	0.1 ppm	0.1 ppm
2-Methoxyethyl acetate (Methyl cellosolve acetate)	110-49-6	25	120	5 ppm	0.1 ppm	0.1 ppm
Methyl acetate	79-20-9	200	610	200 ppm (ST) 250 ppm	200 ppm (ST) 250 ppm	200 ppm (ST) 250 ppm
Methyl acetylene (Propyne)	74-99-7	1000	1650	1000 ppm	1000 ppm	1000 ppm
Methyl acetylene propadiene mixture (MAPP)		1000	1800	1000 ppm (ST) 1250 ppm	1000 ppm (ST) 1250 ppm	1000 ppm (ST) 1250 ppm
Methyl acrylate	96-33-3	10	35	10 ppm	10 ppm	2 ppm
Methylal (Dimethoxy-methane)	109-87-5	1000	3100	1000 ppm	1000 ppm	1000 ppm
Methyl alcohol	67-56-1	200	260	200 ppm (ST) 250 ppm (C) 1000 ppm	200 ppm (ST) 250 ppm	200 ppm (ST) 250 ppm
Methylamine	74-89-5	10	12	5 ppm (ST) 15 ppm	10 ppm	5 ppm (ST) 15 ppm
Methyl amyl alcohol; see Methyl Isobutylcarbinol						
Methyl n-amyl ketone	110-43-0	100	465	50 ppm	100 ppm	50 ppm

OSHA Annotated Table Z-1[(a)]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		Cal/OSHA PEL[(f)] *(as of 4/26/13)*	NIOSH REL[(g)] *(as of 4/26/13)*	ACGIH®2015 TLV®[(h)]
Substance	**CAS No.**[(c)]	**ppm**[(d)]	**mg/m³**[(e)]	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Methyl bromide	74-83-9	(C) 20	(C) 80	1 ppm (ST) 20 ppm	Ca See Appendix A	1 ppm
Methyl butyl ketone; see 2-Hexanone						
Methyl cellosolve; see 2-Methoxyethanol						
Methyl cellosolve acetate; see 2-Methoxyethylacetate						
Methyl chloride	74-87-3	See Annotated Z-2		See Annotated Z-2		
Methyl chloroform (1,1,1-Trichloro-ethane)	71-55-6	350	1900	350 ppm (ST) 450 ppm (C) 800 ppm	(C) 350 ppm [15-min] See Appendix C (Chloroethanes)	350 ppm (ST) 450 ppm
Methylcyclohexane	108-87-2	500	2000	400 ppm	400 ppm	400 ppm
Methylcyclohexanol	25639-42-3	100	470	50 ppm	50 ppm	50 ppm
o-Methylcyclohexanone	583-60-8	100	460	50 ppm (ST) 75 ppm	50 ppm (ST) 75 ppm	50 ppm (ST) 75 ppm
Methylene chloride	75-09-2	See Annotated Z-2		See Annotated Z-2		
Methyl ethyl ketone (MEK); see 2-Butanone						
Methyl formate	107-31-3	100	250	100 ppm (ST) 150 ppm	100 ppm (ST) 150 ppm	50 ppm (ST) 100 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Methyl hydrazine (Monomethylhydrazine)	60-34-4	(C) 0.2	(C) 0.35	0.01 ppm	Ca (C) 0.04 ppm [2-hr] See Appendix A	0.01 ppm
Methyl iodide	74-88-4	5	28	2 ppm	Ca 2 ppm See Appendix A	2 ppm
Methyl isoamyl ketone	110-12-3	100	475	50 ppm	50 ppm	20 ppm (ST) 50 ppm
Methyl isobutyl carbinol	108-11-2	25	100	25 ppm (ST) 40 ppm	25 ppm (ST) 40 ppm	25 ppm (ST) 40 ppm
Methyl isobutyl ketone; see Hexone						
Methyl isocyanate	624-83-9	0.02	0.05	0.02 ppm (ST) 0.06 ppm	0.02 ppm (ST) 0.06 ppm	0.02 ppm (ST) 0.06 ppm
Methyl mercaptan	74-93-1	(C) 10	(C) 20	0.5 ppm	(C) 0.5 ppm [15-min]	0.5 ppm
Methyl methacrylate	80-62-6	100	410	50 ppm (ST) 100 ppm	100 ppm	50 ppm (ST) 100 ppm
Methyl propyl ketone; see 2-Pentanone						
alpha-Methyl styrene	98-83-9	(C) 100	(C) 480	50 ppm (ST) 100 ppm	50 ppm (ST) 100 ppm	10 ppm
Methylene bisphenyl isocyanate (MDI)	101-68-8	(C) 0.02	(C) 0.2	0.005 ppm	0.05 mg/m^3 (C) 0.2 mg/m^3[10-min]	0.005 ppm

OSHA Annotated Table Z-1(a)

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL(b)		**Cal/OSHA PEL(f)** *(as of 4/26/13)*	**NIOSH REL(g)** *(as of 4/26/13)*	**ACGIH®2015 TLV®(h)**
Substance	**CAS No.(c)**	**ppm(d)**	**mg/m^3(e)**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Mica; see Silicates		See Annotated Z-3		See Annotated Z-3		
Molybdenum (as Mo)	7439-98-7					
Soluble compounds			5	0.5 mg/m^3	See Appendix D	0.5 mg/m^3(resp.)
Insoluble Compounds - Total dust			15	10 mg/m^3	See Appendix D	
Insoluble Compounds				3 mg/m^3(resp.)		10 mg/m^3(IHL) 3 mg/m^3(resp.)
Monomethyl aniline	100-61-8	2	9	0.5 ppm	0.5 ppm	0.5 ppm
Monomethyl hydrazine; see Methyl hydrazine						
Morpholine	110-91-8	20	70	20 ppm (ST) 30 ppm	20 ppm (ST) 30 ppm	20 ppm
Naphtha (Coal tar)	8030-30-6	100	400	100 ppm	100 ppm	See *TLV®book* Appendix H
Naphthalene	91-20-3	10	50	10 ppm (ST) 15 ppm	10 ppm (ST) 15 ppm	10 ppm (ST) 15 ppm
alpha-Naphthylamine; see 1910.1004	134-32-7			See Section 5209	Ca See Appendix A	
beta-Naphthylamine; see 1910.1009	91-59-8			See Section 5209	Ca See Appendix A	Exposure by all routes should be carefully controlled to levels as low as possible.
Nickel carbonyl (as Ni)	13463-39-	0.001	0.007	0.001 ppm	Ca	(C) 0.05 ppm

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		Cal/OSHA PEL[f] *(as of 4/26/13)*	NIOSH REL[g] *(as of 4/26/13)*	ACGIH®2015 TLV®[h]
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
	3				0.001 ppm See Appendix A	
Nickel, metal and insoluble compounds (as Ni)	7440-02-0		1	metal 0.5 mg/m^3 insoluble 0.1 mg/m^3	Ca 0.015 mg/m^3 See Appendix A	elemental: 1.5 mg/m^3 (IHL); insoluble inorganic compounds: 0.2 mg/m^3(IHL)
Nickel, soluble compounds (as Ni)	7440-02-0		1	0.05 mg/m^3	Ca 0.015 mg/m^3	soluble inorganic compounds: 0.1 mg/m^3(IHL)
Nicotine	54-11-5		0.5	0.075 ppm	0.5 mg/m^3	0.5 mg/m^3
Nitric acid	7697-37-2	2	5	2 ppm (ST) 4 ppm	2 ppm (ST) 4 ppm	2 ppm (ST) 4 ppm
Nitric oxide	10102-43-9	25	30	25 ppm	25 ppm	25 ppm
p-Nitroaniline	100-01-6	1	6	3 mg/m^3	3 mg/m^3	3 mg/m^3
Nitrobenzene	98-95-3	1	5	1 ppm	1 ppm	1 ppm
p-Nitrochlorobenzene	100-00-5		1	0.1 ppm	Ca See Appendix A	0.1 ppm
4-Nitrodiphenyl; see 1910.1003	92-93-3			See Section 5209	Ca See Appendix A	Exposure by all routes should be carefully controlled to levels as low as possible.
Nitroethane	79-24-3	100	310	100 ppm	100 ppm	100 ppm
Nitrogen dioxide	10102-44-	(C) 5	(C) 9	(ST) 1 ppm	(ST) 1 ppm	0.2 ppm

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		Cal/OSHA PEL[f] *(as of 4/26/13)*	NIOSH REL[g] *(as of 4/26/13)*	ACGIH® 2015 TLV®[h]
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
	0					
Nitrogen trifluoride	7783-54-2	10	29	10 ppm	10 ppm	10 ppm
Nitroglycerin	55-63-0	(C) 0.2	(C) 2	0.05 ppm for mixture of nitroglycerine and ethylene glycol dinitrate (ST) 0.1 mg/m^3	(ST) 0.1 mg/m^3	0.05 ppm
Nitromethane	75-52-5	100	250	2 ppm	See Appendix D	20 ppm
1-Nitropropane	108-03-2	25	90	25 ppm	25 ppm	25 ppm
2-Nitropropane	79-46-9	25	90	10 ppm	Ca See Appendix A	10 ppm
N-Nitrosodimethylamine; see 1910.1016				See Section 5209	Ca See Appendix A	Exposure by all routes should be carefully controlled to levels as low as possible.
Nitrotoluene (all isomers)		5	30	2 ppm	2 ppm	2 ppm
o-isomer	88-72-2					
m-isomer	99-08-1					
p-isomer	99-99-0					
Nitrotrichloromethane; see Chloropicrin						
Octachloronaphthalene	2234-13-1		0.1	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH® 2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
				(ST) 0.3 mg/m^3	(ST) 0.3 mg/m^3	(ST) 0.3 mg/m^3
Octane	111-65-9	500	2350	300 ppm (ST) 375 ppm	75 ppm (ST) 385 ppm [15-min]	300 ppm
Oil mist, mineral	8012-95-1		5	5 mg/m^3(excluding vapor)	5 mg/m^3 (ST) 10 mg/m^3	5 mg/m^3 (IHL; excluding metal working fluids, pure highly and severely refined) (For poorly and mildly refined: exposure by all routes should be carefully controlled to levels as low as possible.)
Osmium tetroxide (as Os)	20816-12-0		0.002	0.002 ppm (ST) 0.006 mg/m^3	0.002 ppm (ST) 0.006 mg/m^3	0.0016 mg/m^3 (ST) 0.0047 mg/m^3
Oxalic acid	144-62-7		1	1 mg/m^3 (ST) 2 mg/m^3	1 mg/m^3 (ST) 2 mg/m^3	1 mg/m^3 (ST) 2 mg/m^3
Oxygen difluoride	7783-41-7	0.05	0.1	(C) 0.05 ppm	(C) 0.05 ppm	(C) 0.05 ppm
Ozone	10028-15-6	0.1	0.2	0.1 ppm (ST) 0.3 ppm	(C) 0.1 ppm	0.05-0.20 ppm depending on workload and time (*See TLV® Documentation on Ozone*)
Paraquat, respirable dust	4685-14-7		0.5			0.1 mg/m^3, as the cation
	1910-42-5			0.1 mg/m^3	0.1 mg/m^3	

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		Cal/OSHA PEL[f] *(as of 4/26/13)*	NIOSH REL[g] *(as of 4/26/13)*	ACGIH®2015 TLV®[h]
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
	2074-50-2					
Parathion	56-38-2		0.1	0.1 mg/m³	0.05 mg/m³	0.05 mg/m³(IFV)
Particulates Not Otherwise Regulated (PNOR)[i]					See Appendix D	See *TLV®book* Appendix B
Total dust			15	10 mg/m³		
Respirable fraction			5	5 mg/m³		
PCB; see Chlorodiphenyl (42% and 54% chlorine)						
Pentaborane	19624-22-7	0.005	0.01	0.005 ppm (ST) 0.015 ppm	0.005 ppm (ST) 0.015 ppm	0.005 ppm (ST) 0.015 ppm
Pentachloronaphthalene	1321-64-8		0.5	0.5 mg/m³	0.5 mg/m³	0.5 mg/m³
Pentachlorophenol	87-86-5		0.5	0.5 mg/m³ (ST) 1 mg/m³	0.5 mg/m³ (ST) 1 mg/m³	0.5 mg/m³ (ST) 1 mg/m³
Pentaerythritol	115-77-5			See PNOR		
Total dust			15	10 mg/m³	10 mg/m³	10 mg/m³
Respirable fraction			5	5 mg/m³	5 mg/m³	
Pentane	109-66-0	1000	2950	1000 ppm	120 ppm (C) 610 ppm [15-min]	1000 ppm
2-Pentanone (Methylpropyl ketone)	107-87-9	200	700	200 ppm (ST) 250 ppm	150 ppm	(ST) 150 ppm

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Perchloroethylene (Tetrachloroethylene)	127-18-4	See Annotated Z-2		See Annotated Z-2		
Perchloromethyl mercaptan	594-42-3	0.1	0.8	0.1 ppm	0.1 ppm	0.1 ppm
Perchloryl fluoride	7616-94-6	3	13.5	3 ppm (ST) 6 ppm	3 ppm (ST) 6 ppm	3 ppm (ST) 6 ppm
Petroleum distillates (Naphtha) (Rubber Solvent)		500	2000	1600 ppm	350 mg/m^3 (C) 1800 mg/m^3[15-min]	See *TLV®book* Appendix H
Phenol	108-95-2	5	19	5 ppm	5 ppm (C) 15.6 ppm [15-min]	5 ppm
p-Phenylene diamine	106-50-3		0.1	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
Phenyl ether, vapor	101-84-8	1	7	1 ppm	1 ppm	1 ppm (ST) 2 ppm
Phenyl ether-biphenylmixture, vapor		1	7		1 ppm	
Phenylethylene; see Styrene						
Phenyl glycidyl ether (PGE)	122-60-1	10	60	0.1 ppm	Ca (C) 1 ppm [15-min] See Appendix A	0.1 ppm
Phenylhydrazine	100-63-0	5	22	5 ppm (ST) 10 ppm	Ca (C) 0.14 ppm [2-hr] See Appendix A	0.1 ppm
Phosdrin (Mevinphos)	7786-34-7		0.1	0.01 ppm	0.01 ppm	0.01 mg/m^3(IFV)

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
				(ST) 0.03 ppm	(ST) 0.03 ppm	
Phosgene (Carbonyl chloride)	75-44-5	0.1	0.4	0.1 ppm	0.1 ppm (C) 0.2 ppm [15-min]	0.1 ppm
Phosphine	7803-51-2	0.3	0.4	0.3 ppm (ST) 1 ppm	0.3 ppm (ST) 1 ppm	0.3 ppm (ST) 1 ppm
Phosphoric acid	7664-38-2		1	1 mg/m^3 (ST) 3 mg/m^3	1 mg/m^3 (ST) 3 mg/m^3	1 mg/m^3 (ST) 3 mg/m^3
Phosphorus (yellow)	7723-14-0		0.1	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
Phosphorus pentachloride	10026-13-8		1	0.1 ppm	1 mg/m^3	0.1 ppm
Phosphorus pentasulfide	1314-80-3		1	1 mg/m^3 (ST) 3 mg/m^3	1 mg/m^3 (ST) 3 mg/m^3	1 mg/m^3 (ST) 3 mg/m^3
Phosphorus trichloride	7719-12-2	0.5	3	0.2 ppm (ST) 0.5 ppm	0.2 ppm (ST) 0.5 ppm	0.2 ppm (ST) 0.5 ppm
Phthalic anhydride	85-44-9	2	12	1 ppm	6 mg/m^3	1 ppm
Picloram	1918-0-21					
Total dust			15	10 mg/m^3	See Appendix D	10 mg/m^3
Respirable fraction			5	5 mg/m^3		
Picric acid	88-89-1		0.1	0.1 mg/m^3	0.1 mg/m^3 (ST) 0.3 mg/m^3	0.1 mg/m^3
Pindone (2-Pivalyl-1,3-	83-26-1		0.1	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^{3}[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
indandione)						
Plaster of paris	26499-65-0			See PNOR		See *TLV®* for calcium sulfate
Total dust			15	10 mg/m^{3}	10 mg/m^{3}	
Respirable fraction			5	5 mg/m^{3}	5 mg/m^{3}	
Platinum (as Pt) Metal	7440-06-4			1 mg/m^{3}	1 mg/m^{3}	1 mg/m^{3}
Soluble Salts			0.002	0.002 mg/m^{3}	0.002 mg/m^{3}	0.002 mg/m^{3}
Portland cement	65997-15-1			See PNOR		
Total dust			15	10 mg/m^{3}	10 mg/m^{3}	
Respirable fraction			5	5 mg/m^{3}	5 mg/m^{3}	1 mg/m^{3} (no asbestos and < 1% crystalline silica)
Propane	74-98-6	1000	1800	1000 ppm	1000 ppm	See *TLV® book* Appendix F
beta-Propriolactone; see 1910.1013	57-57-8			0.5 ppm See Section 5209	Ca See Appendix A	0.5 ppm
n-Propyl acetate	109-60-4	200	840	200 ppm (ST) 250 ppm	200 ppm (ST) 250 ppm	200 ppm (ST) 250 ppm
n-Propyl alcohol	71-23-8	200	500	200 ppm (ST) 250 ppm	200 ppm (ST) 250 ppm	100 ppm
n-Propyl nitrate	627-13-4	25	110	25 ppm	25 ppm	25 ppm

OSHA Annotated Table Z-1[a]

[*Go to list of all footnotes](#)

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		Cal/OSHA PEL[f] *(as of 4/26/13)*	NIOSH REL[g] *(as of 4/26/13)*	ACGIH®2015 TLV®[h]
Substance	**CAS No.**[c]	**ppm**[d]	**mg/m^3**[e]	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
				(ST) 40 ppm	(ST) 40 ppm	(ST) 40 ppm
Propylene dichloride	78-87-5	75	350	75 ppm (ST) 110 ppm	Ca See Appendix A	10 ppm
Propylene imine	75-55-8	2	5	2 ppm	Ca 2 ppm See Appendix A	0.2 ppm (ST) 0.4 ppm
Propylene oxide	75-56-9	100	240	2 ppm	Ca See Appendix A	2 ppm
Propyne; see Methylacetylene						
Pyrethrum	8003-34-7		5	5 mg/m^3	5 mg/m^3	5 mg/m^3
Pyridine	110-86-1	5	15	5 ppm	5 ppm	1 ppm
Quinone	106-51-4	0.1	0.4	0.1 ppm	0.4 mg/m^3	0.1 ppm
RDX: see Cyclonite						
Rhodium (as Rh), metal fume and insoluble compounds	7440-16-6		0.1	0.1 mg/m^3	0.1 mg/m^3	1 mg/m^3
Rhodium (as Rh), soluble compounds	7440-16-6		0.001	0.001 mg/m^3	0.001 mg/m^3	0.01 mg/m^3
Ronnel	299-84-3		15	10 mg/m^3	10 mg/m^3	5 mg/m^3 (IFV)
Rotenone	83-79-4		5	5 mg/m^3	5 mg/m^3	5 mg/m^3
Rouge				See PNOR	See Appendix D	See iron oxide
Total dust			15	10 mg/m^3		

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Respirable fraction			5	5 mg/m^3		
Selenium compounds (as Se)	7782-49-2		0.2	0.2 mg/m^3	0.2 mg/m^3	0.2 mg/m^3
Selenium hexafluoride (as Se)	7783-79-1	0.05	0.4	0.05 ppm	0.05 ppm	0.05 ppm
Silica, amorphous, precipitated and gel	112926-00-8	See Annotated Z-3		See Annotated Z-3		
Silica, amorphous, diatomaceous earth, containing less than 1% crystalline silica	61790-53-2	See Annotated Z-3		See Annotated Z-3		
Silica, crystalline cristobalite, respirable dust	14464-46-1	See Annotated Z-3		See Annotated Z-3		
Silica, crystalline quartz, respirable dust	14808-60-7	See Annotated Z-3		See Annotated Z-3		
Silica, crystalline tripoli (as quartz), respirable dust	1317-95-9	See Annotated Z-3		See Annotated Z-3		
Silica, crystalline tridymite, respirable dust	15468-32-3	See Annotated Z-3		See Annotated Z-3		
Silica, fused, respirable dust	60676-86-0	See Annotated Z-3		See Annotated Z-3		
Silicates (less than 1% crystalline silica)						
Mica (respirable dust)	12001-26-2	See Annotated Z-3		See Annotated Z-3		
Soapstone, total dust		See Annotated Z-3		See Annotated Z-3		

OSHA Annotated Table Z-1[a]

***Go to list of all footnotes**

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Soapstone, respirable dust		See Annotated Z-3		See Annotated Z-3		
Talc (containing asbestos): use asbestos limit: see 29 CFR 1910.1001		See Annotated Z-3		See Annotated Z-3		
Talc (containing no asbestos), respirable dust	14807-96-6	See Annotated Z-3		See Annotated Z-3		
Tremolite, asbestiform; see 1910.1001		See Annotated Z-3		See Annotated Z-3		
Silicon	7440-21-3			See PNOR		See *TLV®-book* Appendix G
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Silicon carbide	409-21-2			See PNOR		Fibrous (including whiskers) 0.1 f/cc Nonfibrous: 10 mg/m^3 (IHL) (no asbestos and < 1% crystalline silica)
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	3 mg/m^3(resp., no asbestos and < 1% crystalline silica)
Silver, metal and soluble compounds (as Ag)	7440-22-4		0.01	0.01 mg/m^3	0.01 mg/m^3	Metal, dust, and fume: 0.1 mg/m^3; Soluble compounds, as

OSHA Annotated Table Z-1[(a)]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[(b)]		Cal/OSHA PEL[(f)] *(as of 4/26/13)*	NIOSH REL[(g)] *(as of 4/26/13)*	ACGIH®2015 TLV®[(h)]
Substance	**CAS No.**[(c)]	**ppm**[(d)]	**mg/m³**[(e)]	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
						Ag: 0.01 mg/m³
Soapstone		See Annotated Z-3		See Annotated Z-3		
Sodium fluoroacetate	62-74-8		0.05	0.05 mg/m³ (ST) 0.15 mg/m³	0.05 mg/m³ (ST) 0.15 mg/m³	0.05 mg/m³
Sodium hydroxide	1310-73-2		2	(C) 2 mg/m³	(C) 2 mg/m³	(C) 2 mg/m³
Starch	9005-25-8			See PNOR		
Total dust			15	10 mg/m³	10 mg/m³	10 mg/m³
Respirable fraction			5	5 mg/m³	5 mg/m³	
Stibine	7803-52-3	0.1	0.5	0.1 ppm	0.1 ppm	0.1 ppm
Stoddard solvent	8052-41-3	500	2900	100 ppm	350 mg/m³ (C) 1800 mg/m³[15-min]	100 ppm
Strychnine	57-24-9		0.15	0.15 mg/m³	0.15 mg/m³	0.15 mg/m³
Styrene	100-42-5	See Annotated Z-2		See Annotated Z-2		
Sucrose	57-50-1			See PNOR		
Total dust			15	10 mg/m³	10 mg/m³	10 mg/m³
Respirable fraction			5	5 mg/m³	5 mg/m³	
Sulfur dioxide	7446-09-5	5	13	2 ppm (ST) 5 ppm	2 ppm (ST) 5 ppm	(ST) 0.25 ppm
Sulfur hexafluoride	2551-62-4	1000	6000	1000 ppm	1000 ppm	1000 ppm

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m³[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Sulfuric acid	7664-93-9		1	0.1 mg/m³ (ST) 3 mg/m³	1 mg/m³	0.2 mg/m³ (Thor.)
Sulfur monochloride	10025-67-9	1	6	(C) 1 ppm	(C) 1 ppm	(C) 1 ppm
Sulfur pentafluoride	5714-22-7	0.025	0.25	(C) 0.01 ppm	(C) 0.01 ppm	(C) 0.01 ppm
Sulfuryl fluoride	2699-79-8	5	20	5 ppm (ST) 10 ppm	5 ppm (ST) 10 ppm	5 ppm (ST) 10 ppm
Systox; see Demeton						
2,4,5-T (2,4,5-tri-chlorophenoxyacetic acid)	93-76-5		10	10 mg/m³	10 mg/m³	10 mg/m³
Talc; see Silicates		See Annotated Z-3		See Annotated Z-3		
Tantalum, metal and oxide dust	7440-25-7		5	5 mg/m³	5 mg/m³ (ST) 10 mg/m³	See *TLV®book* Appendix G
TEDP (Sulfotep)	3689-24-5		0.2	0.2 mg/m³	0.2 mg/m³	0.1 mg/m³(IFV)
Tellurium and compounds (as Te)	13494-80-9		0.1	0.1 mg/m³	0.1 mg/m³	0.1 mg/m³ (excluding hydrogen telluride)
Tellurium hexafluoride (as Te)	7783-80-4	0.02	0.2	0.02 ppm	0.02 ppm	0.02 ppm
Temephos	3383-96-8					1 mg/m³ (IFV)
Total dust			15	10 mg/m³	10 mg/m³	
Respirable fraction			5	5 mg/m³	5 mg/m³	

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		Cal/OSHA PEL[f] *(as of 4/26/13)*	NIOSH REL[g] *(as of 4/26/13)*	ACGIH®2015 TLV®[h]
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
TEPP (Tetraethyl pyrophosphate)	107-49-3		0.05	0.004 ppm	0.05 mg/m^3	0.01 mg/m^3(IFV)
Terphenyls	26140-60-3	(C) 1	(C) 9	(C) 0.5 ppm	(C) 0.5 ppm	(C) 5 mg/m^3
1,1,1,2-Tetrachloro-2,2-difluoroethane	76-11-9	500	4170	500 ppm	500 ppm	100 ppm
1,1,2,2-Tetrachloro-1,2-difluoroethane	76-12-0	500	4170	500 ppm	500 ppm	50 ppm
1,1,2,2-Tetrachloroethane	79-34-5	5	35	1 ppm	Ca 1 ppm See Appendix A See Appendix C (Chloroethanes)	1 ppm
Tetrachoroethylene; see Perchloroethylene						
Tetrachloromethane; see Carbon tetrachloride						
Tetrachloronaphthalene	1335-88-2		2	2 mg/m^3	2 mg/m^3	2 mg/m^3
Tetraethyl lead (as Pb)	78-00-2		0.075	0.075 mg/m^3	0.075 mg/m^3	0.1 mg/m^3
Tetrahydrofuran	109-99-9	200	590	200 ppm (ST) 250 ppm	200 ppm (ST) 250 ppm	50 ppm (ST) 100 ppm
Tetramethyl lead, (as Pb)	75-74-1		0.075	0.075 mg/m^3	0.075 mg/m^3	0.15 mg/m^3
Tetramethyl succinonitrile	3333-52-6	0.5	3	0.5 ppm	3 mg/m^3	0.5 ppm

OSHA Annotated Table Z-1[a]

[*Go to list of all footnotes](#)

		Regulatory Limits			**Recommended Limits**	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Tetranitromethane	509-14-8	1	8	0.005 ppm	1 ppm	0.005 ppm
Tetryl (2,4,6-Trinitrophenylmethylnitramine)	479-45-8		1.5	1.5 mg/m^3	1.5 mg/m^3	1.5 mg/m^3
Thallium, soluble compounds (as Tl)	7440-28-0		0.1	0.1 mg/m^3	0.1 mg/m^3	0.02 mg/m^3(IHL)
4,4'-Thiobis (6-tert,Butyl-m-cresol)	96-69-5					1 mg/m^3 (IHL)
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Thiram	137-26-8		5	5 mg/m^3	5 mg/m^3	0.05 mg/m^3(IFV)
Tin, inorganic compounds (except oxides) (as Sn)	7440-31-5		2	2 mg/m^3; also tin oxide; except SnH_4	2 mg/m^3; except tin oxides	metal, oxide and inorganic compounds, except tin hydride: 2 mg/m^3
Tin, organic compounds (as Sn)	7440-31-5		0.1	0.1 mg/m^3 (ST) 0.2 mg/m^3	0.1 mg/m^{3}except Cyhexatin	0.1 mg/m^3 (ST) 0.2 mg/m^3
Titanium dioxide - Total dust	13463-67-7		15	See PNOR	Ca (ultrafine particles) 2.4 mg/m^3 (fine) 0.3 mg/m^3(ultrafine) [See Appendix A](#) [See Appendix C](#)	10 mg/m^3
Toluene	108-88-3	See Annotated Z-2		See Annotated Z-2		
Toluene-2,4-diisocyanate (TDI)	584-84-9	(C)	(C) 0.14	0.005 ppm	Ca	0.005 ppm

OSHA Annotated Table Z-1[a]

[*Go to list of all footnotes]

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
		0.02		(ST) 0.02 ppm (C) 0.02 ppm	See Appendix A	(ST) 0.02 ppm
o-Toluidine	95-53-4	5	22	2 ppm	Ca See Appendix A	2 ppm
Toxaphene; see Chlorinated camphene						
Tremolite		See Annotated Z-3		See Annotated Z-3		
Tributyl phosphate	126-73-8		5	0.2 ppm	0.2 ppm	5 mg/m^3 (IFV)
1,1,1-Trichloroethane; see Methyl chloroform						
1,1,2-Trichloroethane	79-00-5	10	45	10 ppm	Ca 10 ppm See Appendix A See Appendix C (Chloroethanes)	10 ppm
Trichloroethylene	79-01-6	See Annotated Z-2		See Annotated Z-2		
Trichloromethane; see Chloroform						
Trichloronaphthalene	1321-65-9		5	5 mg/m^3	5 mg/m^3	5 mg/m^3
1,2,3-Trichloropropane	96-18-4	50	300	10 ppm	Ca 10 ppm See Appendix A	0.005 ppm
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	1000	7600	1000 ppm (ST) 1250 ppm	1000 ppm (ST) 1250 ppm	1000 ppm (ST) 1250 ppm

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
				(C) 2000 ppm		
Triethylamine	121-44-8	25	100	(C) 1 ppm	See Appendix D	0.5 ppm (ST) 1 ppm
Trifluorobromomethane	75-63-8	1000	6100	1000 ppm	1000 ppm	1000 ppm
2,4,6-Trinitrophenol;see Picric acid						
2,4,6-Trinitrophenyl-methyl nitramine; see Tetryl						
2,4,6-Trinitrotoluene (TNT)	118-96-7		1.5	0.5 mg/m^3	0.5 mg/m^3	0.1 mg/m^3
Triorthocresyl phosphate	78-30-8		0.1	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
Triphenyl phosphate	115-86-6		3	3 mg/m^3	3 mg/m^3	3 mg/m^3
Turpentine	8006-64-2	100	560	100 ppm	100 ppm	20 ppm
Uranium (as U)	7440-61-1					
Soluble compounds			0.05	0.05 mg/m^3	Ca 0.05 mg/m^3, See Appendix A	0.2 mg/m^3 (ST) 0.6 mg/m^3
Insoluble compounds			0.25	0.2 mg/m^3 (ST) 0.6 mg/m^3	Ca 0.2 mg/m^3 (ST) 0.6 mg/m^3 See Appendix A	0.2 mg/m^3 (ST) 0.6 mg/m^3
Vanadium	1314-62-1					0.05 mg/m^3(IHL) Vanadium pentoxide as V

OSHA Annotated Table Z-1[a]

*Go to list of all footnotes

		Regulatory Limits			Recommended Limits	
		OSHA PEL[b]		**Cal/OSHA PEL[f]** *(as of 4/26/13)*	**NIOSH REL[g]** *(as of 4/26/13)*	**ACGIH®2015 TLV®[h]**
Substance	**CAS No.[c]**	**ppm[d]**	**mg/m^3[e]**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Respirable dust (as V_2O_5)			(C) 0.5	0.05 mg/m^3, vanadium pentoxide	(C) 0.05 mg V/m^3 [15-min], except Vanadium metal and Vanadium carbide	
Fume (as V_2O_5)			(C) 0.1	0.05 mg/m^3	(C) 0.05 mg V/m^3 [15-min]	
Vegetable oil mist				Vegetable oil mists (except castor, cashew nut or similar irritant oils) See PNOR		See *TLV®book* Appendix G
Total dust			15	10 mg/m^3	10 mg/m^3	
Respirable fraction			5	5 mg/m^3	5 mg/m^3	
Vinyl benzene; see Styrene						
Vinyl chloride; see 1910.1017	75-01-4			1 ppm See Section 5210	Ca See Appendix A	1 ppm
Vinyl cyanide; see Acrylonitrile						
Vinyl toluene	25013-15-4	100	480	50 ppm	100 ppm	50 ppm (ST) 100 ppm
Warfarin	81-81-2		0.1	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
Xylenes (o-, m-, p-isomers)	1330-20-7	100	435	100 ppm (ST) 150 ppm (C) 300 ppm	100 ppm (ST) 150 ppm	100 ppm (ST) 150 ppm

OSHA Annotated Table Z-1[(a)]

[*Go to list of all footnotes]

Substance	**CAS No.**[(c)]	**Regulatory Limits**			**Recommended Limits**	
		OSHA PEL[(b)]		**Cal/OSHA PEL**[(f)] *(as of 4/26/13)*	**NIOSH REL**[(g)] *(as of 4/26/13)*	**ACGIH® 2015 TLV®**[(h)]
		ppm[(d)]	**mg/m³**[(e)]	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Xylidine	1300-73-8	5	25	0.5 ppm	2 ppm	0.5 ppm (IFV)
Yttrium	7440-65-5		1	1 mg/m³	1 mg/m³	1 mg/m³
Zinc chloride fume	7646-85-7		1	1 mg/m³ (ST) 2 mg/m³	1 mg/m³ (ST) 2 mg/m³	1 mg/m³ (ST) 2 mg/m³
Zinc oxide fume	1314-13-2		5	5 mg/m³ (ST) 10 mg/m³	5 mg/m³ (ST) 10 mg/m³	5 mg/m³ (ST) 10 mg/m³
Zinc oxide	1314-13-2			See PNOR		
Total dust			15	10 mg/m³	5 mg/m³ (C) 15 mg/m³	
Respirable fraction			5	5 mg/m³		2 mg/m³ (ST) 10 mg/m³
Zinc stearate	557-05-1					See *TLV® Documentation on Stearates*
Total dust			15	10 mg/m³	10 mg/m³	10 mg/m³
Respirable fraction			5		5 mg/m³	
Zirconium compounds (as Zr)	7440-67-7		5	5 mg/m³ (ST) 10 mg/m³	5 mg/m³ (ST) 10 mg/m³	5 mg/m³ (ST) 10 mg/m³

Back to top

Annotated Z-1 Table Footnotes, Abbreviations, References Footnotes

(a) The unshaded area on this page lists PELs from OSHA Table Z-1 in 29 CFR 1910.1000. The shaded area of this page lists other occupational exposure limits (OELs) from Cal/OSHA, NIOSH, and ACGIH®.

(b) Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELS) from 29 CFR 1910.1000 Z-1 Table [58 FR 35340, June 30, 1993; 58 FR 40191, July 27, 1993, as amended at 61 FR 56831, Nov. 4, 1996; 62 FR 1600, Jan 10,1997; 62 FR 42018, Aug. 4,1997; 71 FR 10373, Feb. 28, 2006; 71

FR 16673, Apr. 3, 2006; 71 FR 36008, June 23, 2006.]. PELs are 8-hour time weighted averages (TWAs) unless otherwise indicated. OSHA enforces these limits under section 5(a)(2) of the OSH Act. In addition to the values listed in this table, the Z tables in 29 CFR 1910.1000 list skin absorption designations.
(c) The CAS number is for information only. Enforcement is based on the substance name. For an entry covering more than one metal compound measured as the metal, the CAS number for the metal is given - not CAS numbers for the individual compounds.
(d) Parts of vapor or gas per million parts of contaminated air by volume at 25 degrees C and 760 torr.
(e) Milligrams of substance per cubic meter of air. When entry is in this column only, the value is exact; when listed with a ppm entry, it is approximate.
(f) California Division of Occupational Safety and Health (Cal/OSHA) Permissible Exposure Limits (PELs) from Table AC-1 last updated March 17, 2012, viewable at http://www.dir.ca.gov/title8/5155table_ac1.html. Cal/OSHA enforces its PELs in workplaces under its jurisdiction. Cal/OSHA has established occupational exposure limits for compounds not included in the OSHA Z Tables. Please see Cal/OSHA Table AC-1 for additional limits, the most current limits, and other designations such as skin absorption. The Cal/OSHA AC-1 table and regulations should be consulted for explanations.
(g) National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (RELs) from the NIOSH Pocket Guide to Chemical Hazards (http://www.cdc.gov/niosh/npg) (NIOSH 2007). RELs are for up to 10-hour time weighted averages (TWAs) during a 40-hour work week unless otherwise indicated. NIOSH has established occupational exposure limits for compounds not included in the OSHA Z Tables. Please see the NIOSH Pocket Guide for additional limits, skin absorption and other designations, and explanations.
(h) ACGIH® Threshold Limit Values (TLVs®) (ACGIH® 2015). TLVs® are listed in the order of 8-hour time weighted averages (TWAs), STELs (ST), and Ceilings (C), if available. ACGIH® has established TLVs® for compounds not included in the OSHA Z Tables. Please see ACGIH® *Documentation* for additional limits, skin absorption and other designations, and explanations. The 2015 *TLV® and BEI® Book and Documentation of the Threshold Limit Values on Chemical Substances, 7th Edition* are available through the ACGIH® website at http://www.acgih.org. The TLVs® and BEIs® are copyrighted by ACGIH® and are not publicly available. Permission must be requested from ACGIH® to reproduce the TLVs® and BEIs®. Click here for permission request form.
(i) In 29 CFR 1000, all inert or nuisance dusts, whether mineral, inorganic, or organic, not listed specifically by substance name are covered by the Particulates Not Otherwise Regulated (PNOR) limit which is the same as the inert or nuisance dust limit of Table Z-3.
(j) The final benzene standard in 1910.1028 applies to all occupational exposures to benzene except in some circumstances the distribution and sale of fuels, sealed containers and pipelines, coke production, oil and gas drilling and production, natural gas processing, and the percentage exclusion for liquid mixtures; for the excepted subsegments, the benzene limits in Table Z-2 apply. See 1910.1028 for specific circumstances.
(k) See Table Z-2 for the exposure limits for any operations or sectors where the exposure limits in 1910.1026 are stayed or are otherwise not in effect.
(l) This 8-hour TWA applies to respirable dust as measured by a vertical elutriator cotton dust sampler or equivalent instrument. The time-weighted average applies to the cotton waste processing operations of

waste recycling (sorting, blending, cleaning and willowing) and garnetting. See also 1910.1043 for cotton dust limits applicable to other sectors.

(m) If the exposure limit in §1910.1026 is stayed or is otherwise not in effect, the exposure limit is a ceiling of 0.1 mg/m^3.

Abbreviations

- C = Ceiling limit
- Ca = Potential occupational carcinogens
- CAS No. = Chemical Abstract Service Number
- f/cm^3 = fibers/cubic centimeter
- f/cc = fibers/cubic centimeter
- hr = hour
- IHL = Inhalable
- IFV = Inhalable Fraction and Vapor
- m^3 = cubic meters
- min = Minute
- mg/m^3 = milligrams/meter cubed
- PAH = Polycyclic aromatic hydrocarbons
- PNOR = Particulates not otherwise regulated
- ppm = parts per million
- resp. = respirable
- ST = Short Term Exposure Limit
- Thor. = Thoracic fraction
- TLV® = Threshold Limit Value
- TWA – Time weighted average
- V = Vapor and aerosol

References

ACGIH® 2015 Threshold Limit Values for Chemical Substances in the Work Environment. Adopted by ACGIH® with Intended Changes. See http://www.acgih.org/.

California Division of Occupational Safety and Health (Cal/OSHA) Table AC-1, Permissible Exposure Limits (PELs), in California Code of Regulations (CCR) Title 8 Section 5155, last updated March 17, 2012. Viewable athttp://www.dir.ca.gov/title8/5155table_ac1.html.

National Institute for Occupational Safety and Health (NIOSH) (2007) NIOSH Pocket Guide to Chemical Hazards. Department of Health and Human Services. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health (NIOSH). September 2007. DHHS (NIOSH) Publication No. 2005-149. Available athttp://www.cdc.gov/niosh/docs/2005-149/pdfs/2005-149.pdf

Occupational Safety and Health Administration (OSHA) (2006) Air Contaminants. 29 CFR 1910.1000 [71 FR 16673, April 3, 2006]. Web site accessed on January 30, 2012. Available athttp://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9991

- Main
- **Table Z-1**
- Table Z-2
- Table Z-3

- Important Note on ACGIH TLV®

Annotated OSHA Z-2 Table[a]

*Go to list of all footnotes

Regulatory Limits					Recommended Limits		
OSHA PELs[b]							
			Acceptable maximum peak above the acceptable ceiling concentration for an 8-hr shift		Cal/OSHA PEL[c] *(as of 4/26/13)*	NIOSH REL[d] *(as of 4/26/13)*	ACGIH® 2015 TLV®(
Substance	**8-hour Time Weighted Average (TWA)**	**Acceptable Ceiling Concentration**	**Concentration**	**Maximum Duration**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
Benzene[f] (Z37.40-1969)	10 ppm	25 ppm	50 ppm	10 min	See Annotated Table Z-1		
Beryllium and beryllium compounds (Z37.29-1970)	2 $\mu g/m^3$	5 $\mu g/m^3$	25 $\mu g/m^3$	30 min	0.2 $\mu g/m^3$ (C) 25 $\mu g/m^3$	Ca (C) 0.5 $\mu g/m^3$, See Appendix A	0.05 $\mu g/m^3$(IHL)
Cadmium fume[g](Z37.5-1970)	0.1 mg/m^3	0.3 mg/m^3			See Annotated Table Z-1		
Cadmium dust[g](Z37.5-1970)	0.2 mg/m^3	0.6 mg/m3			See Annotated Table Z-1		
Carbon disulfide (Z37.3-1968)	20 ppm	30 ppm	100 ppm	30 min	1 ppm (ST) 12 ppm (C) 30 ppm	1 ppm (ST) 10 ppm	1 ppm
Carbon tetrachloride (Z37.17-1967)	10 ppm	25 ppm	200 ppm	5 min in any 3 hr	2 ppm (ST) 10 ppm (C) 200 ppm	Ca (ST) 2 ppm [60-min] See Appendix A	5 ppm (ST) 10 ppm
Chromic acid and chromates[h] (Z37-7-1971)		1 $mg/10m^3$			See Chromium (VI) compounds in Annotated Table Z-1		
Ethylene dibromide (Z37.31-1970)	20 ppm	30 ppm	50 ppm	5 min	(C) 0.13 ppm, See Section 5219	Ca 0.045 ppm (C) 0.13 ppm [15-min] See Appendix A	See *TLV® Documen* Ethylene dibromic

Annotated OSHA Z-2 Table[a]

*Go to list of all footnotes

Regulatory Limits						**Recommended Limits**	
OSHA PELs[b]							
			Acceptable maximum peak above the acceptable ceiling concentration for an 8-hr shift		**Cal/OSHA PEL[c]** *(as of 4/26/13)*	**NIOSH REL[d]** *(as of 4/26/13)*	**ACGIH®2015 TLV®(**
Substance	**8-hour Time Weighted Average (TWA)**	**Acceptable Ceiling Concentration**	**Concentration**	**Maximum Duration**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**	**Up to 10-hour TWA** **(ST) STEL** **(C) Ceiling**	**8-hour TWA** **(ST) STEL** **(C) Ceiling**
Ethylene dichloride (Z37.21-1969)	50 ppm	100 ppm	200 ppm	5 min in any 3 hr	1 ppm (ST) 2 ppm (C) 200 ppm	Ca 1 ppm (ST) 2 ppm See Appendix A See Appendix C Chloroethanes	10 ppm
Fluoride as dust (Z37.28-1969)	2.5 mg/m^3				2.5 mg/m^3	2.5 mg/m^3	2.5 mg/m^3 as F
Formaldehyde See 1910.1048					See Annotated Table Z-1		
Hydrogen fluoride (Z37.28-1969)	3 ppm				0.4 ppm as F (ST) 1 ppm as F	3 ppm (C) 6 ppm [15-min]	0.5 ppm as F (C) 2 ppm as F
Hydrogen sulfide (Z37.2-1966)		20 ppm	50 ppm	10 min once only if no other measurable exposure occurs.	10 ppm (ST) 15 ppm (C) 50 ppm	(C) 10 ppm [10-min]	1 ppm (ST) 5 ppm
Mercury (Z37.8-1971)		0.1 mg/m^3			0.025 mg/m^3 for metallic and inorganic	0.05 mg/m^3	0.025 mg/m^3(elem inorganic)
Methyl chloride (Z37.18-1969)	100 ppm	200 ppm	300 ppm	5 min in any 3 hr	50 ppm (ST) 100 ppm (C) 300 ppm	Ca See Appendix A	50 ppm (ST) 100 ppm
Methylene Chloride See 1910.1052					25 ppm (ST) 125 ppm See Section 5202	Ca See Appendix A	50 ppm
Organo (alkyl)	0.01	0.04 mg/m^3			0.01 mg/m^3	0.01 mg/m^3	0.01 mg/m^3

Annotated OSHA Z-2 Table(a)

*Go to list of all footnotes

Regulatory Limits						Recommended Limits	
OSHA PELs(b)							
			Acceptable maximum peak above the acceptable ceiling concentration for an 8-hr shift		Cal/OSHA PEL(c) *(as of 4/26/13)*	NIOSH REL(d) *(as of 4/26/13)*	ACGIH®2015 TLV®(
Substance	**8-hour Time Weighted Average (TWA)**	**Acceptable Ceiling Concentration**	**Concentration**	**Maximum Duration**	**8-hour TWA (ST) STEL (C) Ceiling**	**Up to 10-hour TWA (ST) STEL (C) Ceiling**	**8-hour TWA (ST) STEL (C) Ceiling**
mercury (Z37.30-1969)	mg/m^3				(ST) 0.03 mg/m^3 (C) 0.04 mg/m^3	(ST) 0.03 mg/m^3	(ST) 0.03 mg/m^3
Styrene (Z37.15-1969)	100 ppm	200 ppm	600 ppm	5 min in any 3 hr	50 ppm (ST) 100 ppm (C) 500 ppm	50 ppm (ST) 100 ppm	20 ppm (ST) 40 ppm
Tetrachloroethylene	100 ppm	200 ppm	300 ppm	5 min in any 3 hr	25 ppm (ST) 100 ppm (C) 300 ppm	Ca See Appendix A	25 ppm (ST) 100 ppm
Toluene (Z37.12-1967)	200 ppm	300 ppm	500 ppm	10 min	10 ppm (ST) 150 ppm (C) 500 ppm	100 ppm (ST) 150 ppm	20 ppm
Trichloroethylene (Z37.19-1967)	100 ppm	200 ppm	300 ppm	5 min in any 2 hr	25 ppm (ST) 100 ppm (C) 300 ppm	Ca See Appendix A See Appendix C	10 ppm (ST) 25 ppm

Annotated Z-2 Table Footnotes, Abbreviations, References Footnotes

(a) The unshaded area on this page Lists PELs from OSHA Table Z-2 in 29 CFR 1910.1000. The shaded area of this page lists other occupational exposure limits (OELs) from Cal/OSHA, NIOSH, and ACGIH®.

(b) Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELS) from 29 CFR 1910.1000 Z-2 Table [58 FR 35340, June 30, 1993; 58 FR 40191, July 27, 1993, as amended at 61 FR 56831, Nov. 4, 1996; 62 FR 1600, Jan 10,1997; 62 FR 42018, Aug. 4,1997; 71 FR 10373, Feb. 28, 2006; 71 FR 16673, Apr. 3, 2006; 71 FR 36008, June 23, 2006.]. PELs are 8-hour time weighted averages (TWAs) unless otherwise indicated. OSHA enforces these limits under section 5(a)(2) of the OSH Act. In addition to the values listed in this table, the Z tables in 29 CFR 1910.1000 list skin absorption designations.

(c) California Division of Occupational Safety and Health (Cal/OSHA) Permissible Exposure Limits (PELs) from Table AC-1 last updated March 17, 2012, viewable at http://www.dir.ca.gov/title8/5155table_ac1.html. Cal/OSHA enforces its PELs in workplaces under its jurisdiction. Cal/OSHA has established occupational exposure limits for compounds not included in the

OSHA Z Tables. Please see Cal/OSHA Table AC-1 for additional limits, the most current limits, and other designations such as skin absorption. The Cal/OSHA AC-1 table and regulations should be consulted for explanations.

(d) National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (RELs) from the NIOSH Pocket Guide to Chemical Hazards (http://www.cdc.gov/niosh/npg)(NIOSH 2007). RELs are for up to 10-hour time weighted averages (TWAs) during a 40-hour work week unless otherwise indicated. NIOSH has established occupational exposure limits for compounds not included in the OSHA Z Tables. Please see the NIOSH Pocket Guide for additional limits, skin absorption and other designations, and explanations.

(e) ACGIH® Threshold Limit Values (TLV®s) (ACGIH® 2015). TLV®s are listed in the order of 8-hour time weighted averages (TWAs), STELs (ST), and Ceilings (C), if available. ACGIH® has established TLVs® for compounds not included in the OSHA Z Tables. Please see ACGIH® *Documentation* for additional limits, skin absorption and other designations, and explanations. The 2015 *TLV® and BEI® Book and Documentation of the Threshold Limit Values on Chemical Substances, 7th Edition* are available through the ACGIH® website at http://www.acgih.org. The TLVs® and BEIs® are copyrighted by ACGIH® and are not publicly available. Permission must be requested from ACGIH® to reproduce the TLVs® and BEIs®.

Click here for permission request form.

(f) This standard applies to the industry segments exempt from the 1 ppm 8-hour TWA and 5 ppm STEL of the benzene standard at 1910.1028.

(g) This standard applies to any operations or sectors for which the Cadmium standard, 1910.1027, is stayed or otherwise not in effect.

(h) This standard applies to any operations or sectors for which the exposure limit in the Chromium (VI) standard, Sec. 1910.1026, is stayed or is otherwise not in effect.

Abbreviations

- C = Ceiling limit
- Ca = Potential occupational carcinogens
- CAS No. = Chemical Abstract Service Number
- hr = hour
- m^3 = cubic meters
- mg/m^3= millilgram per cubic meter
- min = minutes
- ppm = parts per million
- IHL = Inhalable
- ST = Short Term Exposure Limit
- TWA = Time Weighted Average
- $\mu g/m^3$ = microgram per cubic meter

References

ACGIH® 2015 Threshold Limit Values for Chemical Substances in the Work Environment. Adopted by ACGIH® with Intended Changes. See http://www.acgih.org/.

California Division of Occupational Safety and Health (Cal/OSHA) Table AC-1, Permissible Exposure Limits (PELs), in California Code of Regulations (CCR) Title 8 Section 5155, last updated March 17, 2012. Viewable athttp://www.dir.ca.gov/title8/5155table_ac1.html.

National Institute for Occupational Safety and Health (NIOSH) (2007) NIOSH Pocket Guide to Chemical Hazards. Department of Health and Human Services. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health (NIOSH). September 2007. DHHS (NIOSH) Publication No. 2005-149. Available athttp://www.cdc.gov/niosh/docs/2005-149/pdfs/2005-149.pdf.

Occupational Safety and Health Administration (OSHA) (2006) Air Contaminants. 29 CFR 1910.1000 [71 FR 16673, April 3, 2006]. Web site accessed on January 30, 2012. Available athttp://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9991.

Annotated TABLE Z-3 Mineral Dusts[a]

***Go to list of all footnotes**

Regulatory Limits				**Recommended Limits**	
	OSHA PEL[b]		**Cal/OSHA PEL[c] 8-hour TWA** *(as of 4/26/13)*	**NIOSH REL[d] Up to 10-hour TWA** *(as of 4/26/13)*	**ACGIH® 2015 TLV®[e] 8-hour TWA**
Substance	**mppcf[f][g]**	**mg/m^3**	**mg/m^3**	**mg/m^3**	**mg/m^3**
Silica: Crystalline					0.025 (resp.) for α-quartz and cristobalite
Quartz (Respirable)	250[h] (%SiO$_2$+5)	10 mg/m^3[k](%SiO$_2$+2)	0.1	Ca 0.05 See Appendix A	
Quartz (Total Dust)		30 mg/m^3(%SiO$_2$+2)	0.3		
Cristobalite	Use ½ the value calculated from the count or mass formulae for quartz.		0.05 (resp.)	Ca 0.05 (resp.) See Appendix A	0.025 (resp.) for α-quartz and cristobalite

Annotated TABLE Z-3 Mineral Dusts[(a)]

*Go to list of all footnotes

Regulatory Limits				Recommended Limits	
	OSHA PEL[(b)]		**Cal/OSHA PEL[(c)] 8-hour TWA** *(as of 4/26/13)*	**NIOSH REL[(d)] Up to 10-hour TWA** *(as of 4/26/13)*	**ACGIH® 2015 TLV®[(e)] 8-hour TWA**
Substance	**mppcf[(f)(g)]**	**mg/m³**	**mg/m³**	**mg/m³**	**mg/m³**
Tridymite	Use ½ the value calculated from the formulae for quartz.		0.05 (resp.)	Ca 0.05 (resp.) See Appendix A	See *TLV® book*Appendix G
Amorphous, including natural diatomaceous earth	20	80 mg/m³ (%SiO_2)	6 (total) 3 (resp.)	6	See *TLV® book*Appendix G
Silicates (less than 1% crystalline silica):					
Mica	20		3 (resp.)	3 (resp.)	3 (resp.)
Soapstone	20		6 (total) 3 (resp.)	6 (total) 3 (resp.)	See Talc
Talc (not containing asbestos)	20[(i)]		2 (resp.)	2 (resp.)	2 (resp., < 1% crystalline silica)

Annotated TABLE Z-3 Mineral Dusts(a)

***Go to list of all footnotes**

Regulatory Limits				**Recommended Limits**	
	OSHA PEL(b)		**Cal/OSHA PEL(c) 8-hour TWA** *(as of 4/26/13)*	**NIOSH REL(d) Up to 10-hour TWA** *(as of 4/26/13)*	**ACGIH® 2015 TLV®(e) 8-hour TWA**
Substance	**mppcf(f)(g)**	**mg/m^3**	**mg/m^3**	**mg/m^3**	**mg/m^3**
Talc (containing asbestos)	Use asbestos limit		See Section 5208	Use asbestos limit Ca 0.1 f/cm^3	Use asbestos TLV®
Tremolite, asbestiform	See 29 CFR 1910.1001			See Appendix A See Appendix C	
Portland cement	50		See PNOR	10 (total) 5 (resp.)	1 (resp., < 1% crystalliine silica and no asbestos)
Graphite (Natural)	15		2.5 (resp.)	2.5 (resp.)	2 (resp., natural, all forms except fibers)
Coal Dust:				1 See Appendix C	0.9 (resp.) bituminous or lignite; 0.4 (resp.) anthracite (Note coal dust should also be monitored for crystalline silica and if present, see *TLV® book*Appendix E for mixtures)

Annotated TABLE Z-3 Mineral Dusts[(a)]

*Go to list of all footnotes

Regulatory Limits				Recommended Limits	
	OSHA PEL[(b)]		**Cal/OSHA PEL[(c)] 8-hour TWA** *(as of 4/26/13)*	**NIOSH REL[(d)] Up to 10-hour TWA** *(as of 4/26/13)*	**ACGIH® 2015 TLV®[(e)] 8-hour TWA**
Substance	**mppcf[(f)(g)]**	**mg/m^3**	**mg/m^3**	**mg/m^3**	**mg/m^3**
Respirable fraction less than 5% SiO_2		2.4 mg/m^3 [(k)]	0.9 (bituminous)		
Respirable fraction greater than 5% SiO_2		10 mg/m^3[(k)](%SiO_2+2)	0.1 (bituminous)		
Inert or Nuisance Dust: [(j)]					See *TLV® Book*Appendix B
Respirable fraction	15	5 mg/m^3	5 (See PNOR)	See Appendix D	
Total Dust	50	15 mg/m^3	10 (See PNOR)	See Appendix D	

Annotated Z-3 Table Footnotes, Abbreviations, References Footnotes

(a) The unshaded area on this page Lists PELs from OSHA Table Z-3 in 29 CFR 1910.1000. The shaded area of this page lists other occupational exposure limits (OELs) from Cal/OSHA, NIOSH, and ACGIH®.

(b) Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELS) from 29 CFR 1910.1000. Z-3 Table [58 FR 35340, June 30, 1993; 58 FR 40191, July 27, 1993, as amended at 61 FR 56831, Nov. 4, 1996; 62 FR 1600, Jan 10,1997; 62 FR 42018, Aug. 4,1997; 71 FR 10373, Feb. 28, 2006; 71

FR 16673, Apr. 3, 2006; 71 FR 36008, June 23, 2006.]. PELs are 8-hour time weighted averages (TWAs) unless otherwise indicated. OSHA enforces these limits under section 5(a)(2) of the OSH Act.

(c) California Division of Occupational Safety and Health (Cal/OSHA) Permissible Exposure Limits (PELs) from Table AC-1 last updated March 17, 2012, viewable at http://www.dir.ca.gov/title8/5155table_ac1.html. Cal/OSHA enforces its PELs in workplaces under its jurisdiction. Cal/OSHA has established occupational exposure limits for compounds not included in the OSHA Z Tables. Please see Cal/OSHA Table AC-1 for additional limits, the most current limits, and other designations such as skin absorption. The Cal/OSHA AC-1 table and regulations should be consulted for explanations.

(d) National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) from NIOSH Pocket Guide to Chemical Hazards (http://www.cdc.gov/niosh/npg) (NIOSH 2007). RELs are for up to 10-hour time weighted averages (TWAs) during a 40-hour work week unless otherwise indicated. NIOSH has established occupational exposure limits for compounds not included in the OSHA Z Tables. Please see the NIOSH Pocket Guide for additional limits, skin absorption and other designations, and explanations.

(e) ACGIH® Threshold Limit Values (TLVs®) (ACGIH® 2015). TLVs® are listed in the order of 8-hour time weighted averages (TWAs), STELs (ST), and Ceilings (C), if available. ACGIH® has established TLVs® for compounds not included in the OSHA Z Tables. Please see ACGIH® *Documentation* for additional limits, skin absorption and other designations, and explanations. The 2015 *TLV® and BEI® Book and Documentation of the Threshold Limit Values on Chemical Substances, 7th Edition* are available through the ACGIH® website at http://www.acgih.org. The TLVs® and BEIs® are copyrighted by ACGIH® and are not publicly available. Permission must be requested from ACGIH® to reproduce the TLVs® and BEIs®.
Click here for permission request form.

(f) Millions of particles per cubic foot of air, based on impinger samples counted by light-field techniques.

(g) Conversion factors - mppcf X 35.3 = million particles per cubic meter = particles per c.c.

(h) The percentage of crystalline silica in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.

(i) Containing less than 1% quartz; if 1% quartz or more, use quartz limit.

(j) All inert or nuisance dusts, whether mineral, inorganic, or organic, not listed specifically by substance name are covered by this limit, which is the same as the Particulates Not Otherwise Regulated (PNOR) limit in Table Z-1.

(k) Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

Aerodynamic diameter (unit density sphere)	**Percent passing selector**
2	90
2.5	75
3.5	50

Aerodynamic diameter (unit density sphere)	**Percent passing selector**
5	25
10	0

The measurements under this note refer to the use of an AEC (now NRC) instrument. The respirable fraction of coal dust is determined with an MRE; the figure corresponding to that of 2.4 mg/m^3 in the table for coal dust is 4.5 mg/m^3.

Abbreviations

- Ca = Potential occupational carcinogens
- f/cm^3 = fibers/cubic centimeter
- mg/m^3 = milligrams/meter cubed
- PNOR = particulates not otherwise regulated
- resp. = respirable
- TLV® = Threshold Limit Value
- TWA = Time weighted average

References

ACGIH® 2015 Threshold Limit Values for Chemical Substances in the Work Environment. Adopted by ACGIH® with Intended Changes. See http://www.acgih.org/.

California Division of Occupational Safety and Health (Cal/OSHA) Table AC-1, Permissible Exposure Limits (PELs), in California Code of Regulations (CCR) Title 8 Section 5155, last updated March 17, 2012. Viewable athttp://www.dir.ca.gov/title8/5155table_ac1.html.

National Institute for Occupational Safety and Health (NIOSH) (2007) NIOSH Pocket Guide to Chemical Hazards. Department of Health and Human Services. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health (NIOSH). September 2007. DHHS (NIOSH) Publication No. 2005-149. Available athttp://www.cdc.gov/niosh/docs/2005-149/pdfs/2005-149.pdf.

Occupational Safety and Health Administration (OSHA) (2006) Air Contaminants. 29 CFR 1910.1000 [71 FR 16673, April 3, 2006]. Web site accessed on January 30, 2012. Available athttp://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9991.

Appendix L: Lists of select carcinogens and substances of high toxicity

Particularly Hazardous Substances

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	9005-42-2	Carcinogen
Metronidazole	443-48-1	Carcinogen
Michler’s ketone	90-94-8	Carcinogen
Mirex	2385-85-5	Carcinogen
Mitomycin C	50-07-7	Carcinogen
Monocrotaline	315-22-0	Carcinogen
5-(Morpholinomethyl)-3-[(5-nitro-furfurylidene)-amino]-2 oxalolidinone	139-91-3	Carcinogen
Mustard Gas	505-60-2	Carcinogen

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

Reproductive Toxins:

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

Materials with High Acute Toxicity

Chemical	**CAS Number**

A

Acrolein	107-02-8
2-Aminopyridine	462-08-8
Arsenic pentafluoride gas	784-36-3
Arsine gas	7784-42-1

B

Benzyl chloride	100-44-7
Boron trifluoride	7637-07-2
Bromine	7726-95-6

C

Chlorine gas	7782-50-5
Chorine dioxide	10049-04-4

Chlorine trifluoride	7790-91-2
Cyanogen chloride	506-77-4

D

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

E

Ethylene chlorohydrin	107-07-3
Ethylene fluorohydrin	371-62-0

F

Fluorine gas	7681-49-4
2-Fluoroethanol	371-62-0

H

Hexamethylene diiosocyanate	822-06-0
Hydrogen cyanide	74-90-8
Hydrogen flouride	7664-39-3

I

Iron pentacarbonyl	13463-40-6
Isopropyl formate	625-55-8

M

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

N

Nickel carbonyl	13463-39-3
Nitrogen dioxide	10102-44-0
Nitrogen tetroxide	10544-72-6
Nitrogen trioxide	10544-73-7

O

Osmium tetroxide	20816-12-0
Oxygen difluoride gas	7783-41-7
Ozone	10028-15-6

P

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

S

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

T

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 Z: Emergency Contact Information

Emergency Contacts

{FOR EMERGENCIES SEE EMERGENCY RESPONSE Guide in Laboratory Safety Plan}

*For immediate emergency service-	8-911
*Northern New England Poison Center:	1-800-222-1222
*Facilities Management –	207-768-9576
*Department and Chemical Hygiene Officer –	207-768-9450
*Campus Safety and Security	207-768-9580
*National Response Center:	1-800-424-8802

Appendix Z: Emergency Contact Information

Emergency Contacts

{FOR EMERGENCIES SEE EMERGENCY RESPONSE Guide in Laboratory Safety Plan}

*For immediate emergency service-	8-911
*Northern New England Poison Center:	1-800-222-1222
*Facilities Management –	207-768-9576
*Department and Chemical Hygiene Officer –	207-768-9450
*Campus Safety and Security	207-768-9580
*National Response Center:	1-800-424-8802