LABORATORY SAFETY PLAN[1]

Lawrence University

Appleton, WI

[1]Modified from Rutgers's University Chemical Hygiene Guide via internet.

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I. Introduction

Lawrence University is concerned for your safety, and is sincere in its efforts to help you avoid injuries which may be caused by hazardous chemicals due to unsafe lab practices or conditions. This Laboratory Safety Plan (LSP) has been developed and implemented to ensure that you have the information and training necessary to work with hazardous chemicals safely, and that your laboratory environment remains a safe place to work. We believe this plan meets the requirements of the OSHA Hazard Communication Standard, Title 29 Code of Federal Regulations 1910.1450(e). The Laboratory Standard requires that this Laboratory Safety Plan be capable of protections employees from health hazards associated with chemicals in the laboratory and that it keeps exposures below occupational exposure limits. At Lawrence University, these occupational exposure limits include either Threshold Limit Values (TLVs), which are established by the American Conference of Governmental Industrial Hygienists (ACGIH) or Permissible Exposure Limits (PELs) promulgated by Federal OSHA, whichever is LOWER. The Laboratory Safety Plan must be readily available to all laboratory employees.

A hazardous chemical is a chemical for which there is statistically significant evidence that acute or chronic health effects may occur in exposed employees or a chemical which poses a physical hazard. The term “health hazard” includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxin, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems and agents which damage the lungs, skin, eyes or mucous membranes. The term “physical hazard” includes chemicals which are flammable, gases under pressure, oxidizers, pyrophoric, organic peroxides or reactive.

The following designates responsibility for implementation of the Laboratory Safety Plan at Lawrence University:

*LABORATORY WORKER/STUDENT – Follows safe work practices, attends required training and is familiar with the LSP

*LABORATORY SUPEREVISOR/PROFESSOR – Assures that all employees/students in the lab follow safe work practices, provides necessary hands-on training, ensures the LSP is available to all occupants of the lab, and provides “prior approval” when necessary.

*CHEMICAL HYGIENE COMMITTEE – Implements the LSP, provides guidance on safe laboratory procedures, and assists in the periodic review and updates of the LSP. Members of this committee shall include an Associate Professor of Chemistry, the Chemistry Laboratory Supervisor, the Biology Laboratory Supervisor, and the Safety Director, who represent the Vice President for Business Affairs who has overall responsibility for the plan.

*UNIVERSITY SAFETY COMMITTEE – Reviews and approves University policy on safety

II. STANDARD OPERATING PROCEDURES

A. Emergency Procedures

1. Priorities

An emergency is any event that requires an immediate stop in work and the following of a special procedure to protect life, health, and property

The best time to know what to do in an emergency is before, not after, it happens. The best time to read the LSP, then, is at your leisure—before the fire begins, and before the chemical is spilled. Though no single plan can possibly cover the range and combination of events that can constitute an emergency, it is the hope that careful reading of the following emergency procedures will help you being the planning process that will best fit your situation. Your experimental protocols or written procedures must always include safety measures, and at times may need to include specific emergency procedures. In any case, all such emergency procedures will need to be practiced and reviewed periodically.

Most emergences will be small, consisting of a single unexpected event. More serious emergencies involve a series of events which stem from an initial incident, expanding in unfortunate sequence. Under any circumstances, decisions may have to be made quickly, often without adequate information, in a context that may have no precedent. Use the best and calmest judgment you have, and try to stay within the following general priorities:

a) LEAVE the area of danger. This is of paramount importance to enable rescuers to do what is necessary to sustain life. If the area includes other people's work space, make sure they leave, too. If you can safely turn off equipment as you go, do so

b) CALL the campus emergency number from the nearest safe area. Calling takes precedence over everything except evacuation in all emergencies. This also applies for seemingly minor emergencies; it is far better to make an occasional unnecessary call than to fail to call and needlessly endanger life or health.

   For ALL emergencies call Campus Security at x6999 or 920-832-6999.

   Calmly state: your name, the location and nature of the emergency, whether an ambulance or firefighting equipment is needed, and hazards that might threaten persons on the scene or responding, and a phone number and location and the scene where you can be reached.

   After calling, stay off the phone. The only exception is in cases of poisoning, when you may need to call the National Poison Control Center: 1-800-222-1222

c) PROTECT the life and health of anyone who may be injured. The First Aid advice given in this plan is contingent on rescue equipment and qualified personnel being 2 or 3 minutes away.

   After calling, do what you can to continue to preserve life, but do no more than the necessary first aid procedures unless you are specifically trained to do so. Subsequent steps will depend on the nature of the emergency and your assessment of its severity. In each of the following situations, be sure you are in a safe place, summon help quickly, and try to protect the lives of those involved.

2. Injury First Aid

Ideally, only people with first aid training should render first aid. In an emergency, however, untrained help may be better than none. Stay calm, do only what you must before help arrives, and follow these priorities

a) REMOVE THE VICTIM FROM THE AREA OF DANGER—fire, spill, fumes, etc. if the victim is not conscious, DO NOT ENTER THE AREA and proceed immediately to step 2, "Call for help."

[NOTE: If the victim is in contact with electricity, he or she becomes “the area of danger.” Avoid direct physical contact with the injured and the source of power; disconnect the power or push/pull the victim away from the circuit with a non-conductive material (board, rope, etc.)].

b) **CALL FOR HELP 911.**

Always initiate the process to get trained medical help before you take any other extensive action. For a serious injury (very heavy bleeding, chemical in the eyes, etc.), you will often need to stabilize the situation briefly before calling. Common sense will dictate this potentially difficult decision, but in no case should calling be delayed except for the most immediate life-threatening situation.

If two people are available, one can go for help while the other begins first aid.

c) REESTABLISH AIRWAY for breathing, if breathing has stopped.

Check for an object blocking the airway; remove it if possible. Only if there is no blockage should artificial respiration be attempted; otherwise the victim could be injured further

Lift the victim’s neck and tilt the head back to open the airway. Pinch the victim’s nostrils and cover the mouth with yours. Blow your breath into the victim’s mouth until you see the chest rise. Remove your mouth and let the victim exhale while you breathe in.

Repeat 15 times per minute until the victim starts breathing or help arrives. DO NOT STOP, even if you think there is no hope.

d) CONTROL BLEEDING by applying direct pressure to the wound, using a clean cloth or your hand. If possible, elevate the injured area above the heart. Keep the victim warm and lying down. Never use a tourniquet except for amputated or crushed limbs.

e) REESTABLISH CIRCULATION through cardio-pulmonary resuscitation (CPR). Only those trained in this procedure should attempt it.

Training is available through the Wellness Center. Contact the Director of Aquatics or the Director of Wellness and Recreation for information.

f) Treat for CHEMICAL CONTACT

If the chemical was ingested, call the campus emergency number and then the Poison Control Center (1-800-222-1222). Follow their instructions. If for some reason you cannot reach professional advice, do not give the victim water, milk or anything else unless so directed by a Material Safety Data Sheet (MSDS) or other text. Do not induce vomiting if the victim complains of pain or a burning sensation in the mouth or throat, or if the ingested substance is known to be caustic, a cleaning fluid or a petroleum product. Induce vomiting only if directed to do so by Poison Control. To induce vomiting, place the victim’s head below the hips, mouth down or to the side, and place a finger at the back of the victim’s throat.

If the chemical was inhaled and the victim is conscious, call the campus emergency number and then carry or drag the victim to fresh air. Do not let the victim walk unassisted or engage in any unnecessary activity that will increase the circulation of poison in the bloodstream. If you need to use artificial respiration, be careful you do not inhale the poison from the victim. If the victim is not conscious, do not enter the area; the victim may have been overcome by gases in the area, or by lack of oxygen in the space. There have been many documented instances of would-be rescuers becoming additional victims.

If the chemical was splashed in the eye, immediately seek an eyewash, safety shower or spigot. The eye must be water for at least 15 minutes with the eyelids held apart to allow maximum exposure of the eyeball. While washing, check for contact lenses by looking into the eye, and by asking the victim (while contact lenses are prohibited in laboratories where chemicals are used, rules are sometimes broken). Ask the victim to remove them if possible. Otherwise, contacts may be removed under gentle water pressure. Do not attempt to remove contacts by hand or with any other object. Emergency personnel are trained to do this. Be careful not to rub the eyes.

If chemicals are on the skin, follow the recommendations under the First Aid section of the MSDS. If such information is not readily available, wash the affected area with continuous clean water for 15 minutes. Remove all clothing contaminated with chemicals; be careful that the rescuer does not become contaminated as well

Be aware of the possibility of inadvertent injection or unnoticed introduction of chemicals into the body. Many solids, oily liquids or water solutions can enter through cuts in the skin. In addition, many oily liquids and oil-soluble solids will be absorbed by the skin. Keep the victim quiet and wait for medical assistance.

g) Treat for SHOCK

Though in appearance less dramatic than the above injuries, shock can kill just a quickly. If a person goes into severe shock, treatment for shock takes priority over all First Aid except for reestablishing airway, control of bleeding, and CPR.

Symptoms of shock include paleness, cold and clammy skin, weakness, nausea/vomiting, shallow breathing, rapid pulse, cold seat, chills and shaking

If possible, remove the cause of shock (e.g. control heavy bleeding). Keep the victim warm and lying down. Elevate legs if no spinal or head injuries are suspected. Keep the airway open and give non-alcoholic liquids if the victim can swallow and does not have a "belly wound."

3. Fires and Explosions

a) LEAVE the area of danger – usually the building. When needed, use a fire extinguisher to clear a safe path, or "shoot your way out." Do not stay to fight large fires.

b) CALL the campus emergency number. The emergency number should be called, or the building alarm sounded, for all unintentional fires, without exception.

c) Be sure that others in the area of the first are notified as well, whether verbally or through the fire alarm. If you hear a fire alarm (a loud horn), immediately leave the building, making sure others do as well.

d) On your way out, turn off equipment and move explosive materials away from possible heat, ONLY IF THERE IS SAFE TIME TO DO SO. Your leaving quickly is the HIGHEST PRIORITY.

e) In determining the nearest safe place, be aware of the possible spread of toxic gases and fumes, including the likely direction of spread (for example, gases heavier than air will accumulate in low places). When the Fire Department arrives, tell them which chemicals are involved.

f) If a person's clothing is on fire, he or she must not be allowed to run, as this will fan the flames and cause a more serious burn. Douse with water or wrap in a fire blanket, coat, or whatever is available to extinguish the fire. Roll the person on the floor if necessary. After calling the emergency number, place clean, wet, ice-packed cloths on the burned areas, wrap the person warmly to avoid shock, and wait for assistance.

g) The primary purpose for fire extinguishers is to "shoot your way out" in order to reach safety; fire fighting is always better done by those with the equipment and training to do it. Know in advance which type of extinguisher is appropriate for which type of fire (consult the data on the extinguisher); be sure to use the appropriate extinguisher, and direct the discharge at the base of the flames. Training on the proper use of fire extinguishers is available through Facilities Services. Contact the Campus Safety Officer for more information.

h) A fire contained in a small vessel can usually be smothered by covering the vessel with an inverted beaker or glass watch. Do not use dry paper towels or cloths. Remove nearby flammable materials while the fire burns itself out.\

4. Chemical Spills

Procedures for handling spills in laboratories are given in Appendix 2. The flow chart which is included should be copied and posted in the laboratory. If there has been any chemical contamination of personnel or clothing, follow Emergency Procedures for Chemical Contact (see section 2.f above).

5. Indentifying Hazardous Substances in Emergencies

To help indentify hazardous substances involved in an emergency, Lawrence has established a Caution Sign program which provides for door signs bearing the room supervisor's name and phone number and a listing of potential hazards in the room. Caution signs may be obtained or updated by calling Facilities Services. A copy of the Caution Sign program is given in Appendix 3.

6. Reporting Accidents

In the event of a laboratory accident, an Accident Report Form must be completed by the supervisor or instructor and sent to Human Resources within 48 hours of the accident. This form contains valuable information to help determine causes and prevent future accidents in the laboratory, and should be completed for all laboratory accidents, no matter how minor.

A copy of the form is given in Appendix 4. Anyone needing additional copies of the form can contact Human Resources. Additional information is available in the **University Health/Safety Manual**.

7. Power Failures

If your laboratory loses power during an emergency, leave the building as quickly as possible by following your department's building evacuation plan. Call the campus emergency number from the nearest safe area to report the power failure and away assistance.

B. General Laboratory Behavior

1. Safety Rules

a) Know the location of laboratory and building exits.

b) Know the location and use of the safety showers and eyewashes.

c) Know the location and use of fire extinguishers.

d) Know the location and use of spill kits

e) Know the location of the nearest phone which can be used in an emergency

f) Know the potential hazards of the materials, facilities, and equipment with which you will work. If you are uncertain, ask your instructor or supervisor.

g) Use the proper safety equipment for your procedure. This could include a fume hood, gloves, biosafety cabinet, shield, or other equipment.

h) Do not wear contact lenses in laboratories where chemicals are used.

i) Wear eye protection in the library. Splash goggles are required for wet chemical work or work with dusts and powders.

j) Wear other personal protective equipment (PPE) where laboratory or experimental conditions dictate. This includes aprons, lab coats, gloves, glass blowers' goggles, face shields, dust masks, respirators. (Anyone requiring respiratory protection must participate in the Lawrence Respiratory Protection program. Contact the Safety Director for more information.)

k) Wear clothes that protect the body against chemical spills, dropped objects, and other accidental contact. Thus, bare midriffs, shorts, open shoes, sandals, and high heels are prohibited.

l) Confine long hair when in the laboratory. Remove or secure ties and other articles of clothing or jewelry that might become entangled in equipment

m) Do not eat, drink, smoke, or apply cosmetics in the laboratory. Do not store food or drink in the laboratory, or use laboratory equipment for eating or drinking.

n) Do no pipet by mouth. Use only mechanical pipetting devices.

o) Wash hands frequently when handling chemicals and before leaving the laboratory. Beware of contamination of clothing or of door knobs, frames, etc. Remove any protective gear before leaving the laboratory; this includes gloves and laboratory coats.

p) Follow written protocols or instructions. Perform only authorized experiments. (See Sec. E, "Laboratory Operations Which Require Prior Approval.")

q) Do not move or disturb equipment in use without consent of the user.

r) For reasons of safety and security, it is prudent to avoid working alone in the laboratory, particularly after hours. The Laboratory Supervisor is responsible for determining and implementing procedures to provide for emergency notification and periodic checks of an individual working "alone" in the laboratory. The extent of the procedures is dependent on the nature of the laboratory work and the degree of the potential hazard.

s) Do not play in the laboratory.

t) Follow good housekeeping practices – clean up as you go, keep work areas, aisles, and exits uncluttered.

u) Do not deface labels on chemical containers. Make sure all container labels correctly identify their contents.

v) Report all accidents and injuries immediately to your laboratory instructor, supervisor, or Chemical Hygiene Officer

w) Report unsafe conditions to your instructor, supervisor, or Chemical Hygiene Officer

2. Additional Safety Rules for Students

a) Read and follow the Safety Rules listed previously

b) Know who is in charge of your laboratory

c) Perform only authorized experiments, and be sure you understand the procedures involved before you begin. If anything unexpected, dangerous, threatening, or unmanageable happens, immediately call you instructor.

d) Do not use unfamiliar equipment without instruction and permission.

e) Behave and dress appropriately for conscientious work in a potentially hazardous place. Never play in the laboratory.

f) Report all accidents and injuries, however small, to your instructor.

3. Additional Safety Rules for Instructors and Supervisors

a) Take responsibility, in attitude and action, for the safety conditions of your laboratory.

b) Observe all rules and see that they are enforced.

c) Set an example by wearing protective equipment and by following proper laboratory procedures to promote safe work habits.

d) Carefully review all laboratory experiments for possible safety problems before the experiments are assigned to students.

e) Make both preventative and remedial safety measures part of your instruction. Be sure all students and laboratory workers are familiar with emergency procedures and equipment.

f) Be alert for unsafe conditions. Inspect often and intelligently; take effective corrective action promptly.

g) Assume responsibility for visitors and require that they follow the same rules as students and other laboratory workers.

h) Keep a current file of publications on laboratory safety. Encourage its use. See Section D on Employee Information and Training.

4. Rules for Custodial Workers

a) You may sweep, mop, wash the floors, and remove normal trash from any laboratory, including a radiation laboratory.

b) Rooms which have a Caution Sign and any of the nine different stickers on the door may contain materials or equipment which, if used improperly, may cause harm.

c) Do not touch any material, container, or waste container which a biohazard symbol or radiation symbol on it.

d) You must not touch, disturb, move, or handle any containers of any chemicals or materials except those issued to you by your department. If you need chemicals or other laboratory materials moved in order to perform your duties, have the Laboratory Supervisor arrange for this to be done or contact your supervisor.

e) If the contents of any containers (other than those issued to you) are spilled, DO NOT TOUCH THEM OR ATTEMPT TO CLEAN THEM UP. Tell your supervisor, who will then contact emergency personnel.

f) Wear safety glasses if there are persons working in the laboratory

g) Do not eat, drink, smoke, or apply cosmetics in a laboratory.

h) If you have any questions, contact your supervisor

i) Annual cleaning of laboratories must be arranged with the Laboratory Supervisor prior to cleaning.

5. Rules for Maintenance Workers

a) Before working in a laboratory, or on a chemical fume hood, inform the Laboratory Supervisor what you will be doing, and when you will be working.

b) The Laboratory Supervisor is responsible for assuring that your work area within the room is free from physical, chemical, and/or biological hazards. Your work area may include hoods, sinks, cabinets and benches, bench tops, floors, and/or equipment. You may be required to repair, move, remove, replace, paint, etc. as part of your duties.

c) Do not handle or move chemicals in the laboratory. If you need chemicals moved in order to perform you duties, have the Laboratory Supervisor arrange for this to be done.

d) Generally, you should not move or handle equipment in the laboratory. If you work requires you to move, remove, or replace a piece of equipment, have the Laboratory Supervisor assure you that the equipment is free of any physical, chemical, and/or biological hazards.

e) Do not eat, drink, smoke or apply cosmetics in the laboratory.

f) In situations where the hazard cannot be totally removed, specifics work procedures will be developed in conjunction with the department supervisor. If there is a chance your work may bring you in contact with chemical hazards (e.g. working on laboratory sinks, working in areas where this is a chance of chemical contamination) or when working in rooms where chemical experiments are taking place, have the Laboratory Supervisor provide you with the necessary personal protective equipment (PPE), including gloves, goggles, etc.

g) When working on a fume hood, ask the Laboratory Supervisor if the hood was used for perchloric acid or radioactive materials. Contact Facilities Services before performing maintenance on any part of a perchloric acid or radioactive materials fume hood system (including: hood, base, duct, fan, stack, etc.). Lubricate perchloric acid hood fans with fluorocarbon grease only.

h) If you are working in a room labeled with a radiation symbol, refer to the handout "Maintenance Staff – Procedures for Dealing with Equipment in Laboratories Using Radioactive Materials."

i) If you have any questions, contact the Laboratory Supervisor or you supervisor

C. Safety Systems

1. Personal Protective Equipment

a) Eye Protection

i. Splash Goggles

Eyes are particularly sensitive to any contact with chemicals; therefore splash goggles must be worn at all times in laboratories where liquid chemicals, dusts, or powders are being used. Safety glasses do not offer sufficient protection from fumes or particles entering from the side.

ii. Shields

Standing shields and face shields protect the face and neck. Shields of good rigidity and strength which protect the face and neck should be used for vacuum work, when working with low or high pressure systems or where mild explosions may be anticipated.

b) Respiratory Protection

Dust masks, cartridge respirators, self-contained breathing apparatus, or any other type of respiratory protection should not be necessary in a probably designed laboratory. If you believe you may nevertheless require such protection, contact the Campus Safety Director for information and recommendations. See also Appendix 2, Lawrence University Respirator Program.

c) Skin and Body Protection

i. Gloves

Gloves protect the hands against contact with chemicals and also against abrasion and extremes of heat and cold. Check gloves before use for worn spots, cracks and other signs of wear. When removing gloves, be careful to avoid touching the outside of the gloves with your bare hands also avoid touching door knobs, light switches, etc., with the gloves. Always remove gloves (and all other protective gear) before leaving the laboratory.

Different kinds of gloves offer different levels and types of protection. Gloves made from cotton or cotton with leather protects against abrasion, sharp objects, and glass; however, they offer virtually no wet chemical protection, and may actually absorb chemicals and keep them in contact with the skin. Surgical-type gloves made of rubber or synthetics offer some hand protection and also allow dexterity. For more substantial protection against some acids and most other corrosive, heavy rubber gloves are available with various lengths of forearm protection. Heavy rubber gloves do not effectively protect against a number of concentrated acids, organic solvents, or PCBs. These substances require gloves made of a synthetic material, for example neoprene nitrile rubber or Viton, depending on the chemical being used. Insulated gloves should be used when dealing with temperature extremes. Proper fit and comfort must also be considered when selecting gloves

ii. Aprons and Lab Coats

Aprons and lab coats protect the body as gloves do the hands. Heavy rubber aprons should be used for protection against strong acids and bases. As discussed above, heavy rubber will not protect against all materials, in which case a synthetic material must be used. Vinyl aprons are recommended for general use; cloth lab coats are also useful, but mainly for protecting clothing.

As with gloves, lab coats and aprons should remain in the laboratory. Many of the substances which are found in the laboratory can be inadvertently taken home on lab coats and aprons.

iii. Shoes

Sturdy closed-toed shoes should be worn in the laboratory at all times to protect against spills and splashes which reach the floor. Leather shoes offer better protection against corrosion than canvas shoes; open-toed shoes are prohibited in the laboratory.

d) Hearing Protection

Standards for hearing protection and acceptable noise levels have been established by PEOSHA regulations. If you feel that a noise hazard is present in your laboratory, contact Facilities Services for evaluation and recommendations.

2. Fire Protection (Fire Extinguishers)

Everyone working in a laboratory must know the location and correct use of fire extinguishers. Although extinguishers are capable of putting out small, contained fires, their primary purpose is to allow you to "shoot your way out" – to establish and maintain a safe exit path as you leave.

It is important to use the right kind of fire extinguisher for the fire. The classes of fires are identified by letter:

A – Ordinary combustible solids including paper, wood, coal, rubber, and textiles

B – Flammable and other combustible liquids, including gasoline, diesel fuel, alcohol, motor oil, grease, and flammable solvents.

C – Electrical equipment.

D – Combustible or reactive metals (such a sodium and potassium), metal hydrides, or organometallics (such as alkyl aluminums).

Each fire extinguisher is clearly marked by the letter(s) of the class of fire that it can extinguish. Because using the wrong kind of extinguisher can be very dangerous, the time to read the extinguisher is before the fire at your leisure.

Fire extinguishers are supplied and maintained by the university Facilities Services, who can be contacted with any questions.

3. Laboratory Equipment

a) *Fume Hoods*

Fume hoods are a common means of control of exposure to toxic substances. The variety of hood used should depend on the materials involved; for example, hydrofluoric acid will etch glass, perchloric acid requires a stainless steel hood interior and duct and wash-down system and radioisotopes may require stainless steel ducts.

A chemical fume hood is designed to operate most effectively at an optimum air velocity, usually 80 – 100 linear feet per minute. While it is good practice to work with the sash as low as possible, this measurement is made with the sash fully open to ensure protection at any sash height. This air velocity will result in a laminar air flow pattern which will capture most fumes and vapors likely to be given off within the hood.

Lower air velocities may be insufficient to capture and remove most fumes and vapors. Higher velocities can lead to a turbulent air flow which does not capture the fumes and vapors as well. Facilities Services annually surveys all fume hoods within the university to determine if they are operating at acceptable levels. If your fume hood does not have an inspection sticker, or if you have a new hood, please contact Facilities Services.

The following are guidelines are for safe fume hood use, and are to be followed when using a fume hood. All laboratory supervisors should periodically review these procedures with all laboratory personnel.

i. Be sure that the hood is turned on before you start an operation. After an electrical power outage, the hood will need to be restarted.

ii. Use the fume hood with the sash as low as possible, at or below the indicated operating height. The operating height should be clearly marked by arrows on either side of the sash track. These marks are on a hood when it is surveyed by Facilities Services. If your fume hood does not have an operating height sticker on it, call Facilities Services as the hood probably has not been surveyed. If you need to move large pieces of equipment into or out of the hood, raise the sash for as long as is necessary, and lower it as soon as possible. Do not work in the hood with the hood sash fully open. The fume hood operates more effectively with the sash at the operating height. Additionally, this will allow the sash to serve as a physical barrier between your face and the contents of the fume hood.

iii. Do not store in the hood chemicals or equipment which are not currently being used.

iv. Raise large pieces of equipment up approximately 2" on blocks, to allow air to pass under the equipment and allow more even air flow through the hood.

v. Do not place equipment or chemicals very close to the clot openings in the baffles at the rear of the hood, or very close to the front edge of the hood. Putting items in these spots will interfere with even air flow through the hood. Keep materials at least 6" back from the front edge.

vi. Keep the sash glass clean, and never obstruct you view through it with paper, notices, decals, or other items.

vii. Avoid sudden movement past the face of the hood when it is operating. Simply walking briskly past the hood can disrupt air currents and pull vapors out of the hood.

viii. Keep your head outside the fume hood. Do not walk into a "walk-in" hood when it is operating. "Walk-in" hoods are designed to hold large pieces of equipment and are not to be literally "walked-into."

ix. NEVER use perchloric acid in a fume hood not specifically designed for this purpose. A properly designed perchloric acid hood has a stainless steel liner, with a stainless steel duct that runs vertically to the roof. It is designed with a water wash-down system to periodically remove dangerous perchloric acid residues. Using perchloric acid in a conventional fume hood can leave explosive residues on the hood, duct or fan.

x. If your hood is equipment with a flow-indicating device, check to see that it is functioning properly before use. If your hood is not equipped with a flow-indicating device, you can periodically check it with a hand-held velocity meter or by hanging a Kimwipe from the bottom of the hood sash. This should be drawn in when the hood is operating normally, and will hang straight down when the hood is operating marginally or not at all. If your fume hood is not operating properly, first check to see that it is on and that the rear slots are not blocked. If that is not the problem, then contact Facilities Services immediately to have it repaired

Keep in mind that a chemical fume hood is an important piece of laboratory safety equipment. Using and maintain a fume hood properly will help protect you and your fellow workers from potential chemical hazards in the laboratory. If you have questions about fume hood use, or need training on the proper use of a chemical fume hood, please contact your Laboratory Supervisor.

b) Glove Boxes

Where highly toxic substances must be3 contained, or reactive substances must be handled in an inert or dry atmosphere, it may be necessary to use a completely enclosed unit such as a glove box.

c) Eye Washes

An emergency eyewash unit should be located in every laboratory and should deliver a gentle flow of clean, aerated water. The eyewash must be kept free of obstructions.

When a chemical has splashed into the eye, irrigate the eye immediately. Flush the eye with a copious amount of water under gentle pressure. If the victim is wearing contact lenses, have him or her remove them at once if possible. Forcibly hold the eye open to wash thoroughly behind the eyelids. The victim must be given prompt medical attention regardless of the severity of the injury. Continue irrigating for 15 minutes before transport to a hospital or health center.

Eyewash units are installed and maintained by Facility Services, and tested quarterly. The using department determines the need and location for new showers and eyewash stations. If there is a need in your department, contact Facilities Services.

d) Safety Showers

Each laboratory where hazardous chemicals are used should have a safety shower in an easily accessible location. The shower area must be kept clear of obstructions.

In case of chemical contamination over a large part of the body, the contaminated clothes must be removed immediately and the person doused with water continuously for 15 minutes or until medical help arrives. A blanket can be used for warmth and modesty during dousing. Someone should be sent at the beginning of this procedure to summon medical attention.

e) Ground Fault Circuit Interrupters

A ground fault circuit interrupter is an electrical device that protects against leakages of electrical current to ground. If even a minor leakage is detected, the device opens the circuit, preventing possible electrocution. Ground fault circuit interrupters can be portable—placed within the laboratory when needed—or installed in the circuit box itself by Facilities Services. These devices are required where damp or wet conditions are likely.

f) Spill Containment

Use absorbent paper on the bench top to contain small spills. Absorbent paper will also help reduce possible contamination of the laboratory furniture and apparatus. Procedures using larger amounts of liquid should be performed in or over spill trays. Spill kits of absorbent material should be available for containment and neutralizing of large spills. Be sure to use each kit only for the materials designated on the kit container. All spills requiring the use of a kit should be reported to the campus emergency number.

D. Preparing for Laboratory Work

Before beginning any laboratory work, a plan should be made describing: goals, chemicals and equipment needed and the sequence of steps to be followed, including safety measures.

1. Chemicals

Full descriptions of chemicals used in the laboratory can be found on the Material Safety Data Sheets (MSDSs) or other reference materials, which contain information on physical characteristics, hazards, disposal, and routine and emergency precautions. An MSDS is acquired for every chemical used and is kept on file in or near the department stockroom for reference. The information on the MSDS should be given to every laboratory worker who will be handling the chemical in question. Design your procedure to use the least hazardous chemicals and the minimum possible quantity of each chemical that will still allow meaningful results. Using smaller quantities of chemicals means that less can be spilled or volatilized, and that less must be treated and/or disposed as hazardous waste.

2. Equipment

Specific information must be obtained about any equipment to be sued. Most equipment is sold with this information, ranging from one page instruction sheets to complete books. This information must be read thoroughly and followed exactly for safest use of the equipment. When used equipment is sold or donated to the university, recipients must obtain operating instructions if at all possible.

3. Written Procedures

Developing a protocol is basic to the experimental process, and should result in a written set of procedures. Writing the procedures allows the researcher or instructor to go through the experiment in the planning stage, and identify areas where special precautions may be necessary. The written protocol will provide workers with step-by-step instructions, minimizing the chance of errors. A good written protocol will allow for modifications and will include safety precautions (e.g. “wear splash goggles,” “pour acid into water,” “perform this operation in the fume hood”). In addition, a laboratory notebook should be kept during the procedure, documenting each action and its result. In the event of an accident, a set of written procedures and laboratory notebook may indicate what when wrong and possibly why.

E. General Laboratory Equipment Setup

1. Preparing the Workspace

Workspace should be uncluttered. Only necessary materials, equipment, protocols, instructions, notebook, and pen or pencil should be present. Books, unnecessary materials, and scraps of paper should be removed and stored properly. Keep measuring equipment, such as glass cylinders, where it will not be easily knocked over. Do not place equipment on the floor of a working area where it may trip others or be knocked over.

Use only equipment that is free of flaws (cracks, chips, inoperative switches, frayed cords, etc.). Ensure that all necessary guards are in place before using equipment. Examine glassware carefully. All defective glassware should be returned to the stockroom for replacement, or should be discarded safely. All defective electrical equipment must be repaired before use or discarded.

Set up clean, dry apparatus, firmly clamped and well back from the edge of the laboratory bench. Keep burners and open flames a safe distance from solvents and reagent bottles. Allow enough space for the equipment used, and enough working space to avoid crowding other workers and disturbing their apparatus. Select vessels of the proper capacities for each experiment.

Place a tray or absorbent paper under the apparatus to confine spilled liquids.

All equipment must be properly supported to prevent unnecessary movement and to maintain proper alignment during the experiment. Apparatus attached to a ring stand should be positioned so that the system's center of gravity is over the base and not to one side. Securely attach clamps to stands. Set up the equipment with adequate space and configuration for removing burners or baths. Orient equipment so that stopcocks, hoses, and other attachments will not be loosened by gravity. Use a retainer or spring where necessary.

Use a fume hood if the experiment is expected to evolve noxious orders, or toxic or flammable gases, vapors, or fumes. Do not use perchloric acid, hydrofluoric acid, or radioisotopes in hoods that are not specifically approved for those materials.

Use a protective shield when conducting a reaction which may result in a mild explosion or when using a vacuum system (which may implode). Use a face shield that is sufficiently large and strong to protect your face and neck, or use a standing shield. A standing shield is indicated if an explosion is likely. Standing shields must be adequately stabilized with weights or fasteners to prevent their being knocked over by an explosion, and should be secured near the top. Eye protection must be work even when using the shields.

2. Glassware

Pyrex or borosilicate glassware is recommended for all laboratory glassware except for special experiments which use ultraviolet or other light resources. The only soft glass provided in the laboratory should reagent bottles, measuring equipment, stirring rods, and tubing. Any sizable non-spherical glass equipment to be evacuated, such as suction flasks, should be specifically designed with heavy walls. Dewar flasks and large vacuum vessels should be taped or otherwise screened or contained in a metal jacket to avoid flying glass from an implosion. Thermos bottles, with thin walls, are not adequate substitutes for Dewar flasks.

Large bottles and jars containing acids or corrosive chemicals should only be moved in suitable acid bottle carriers, such as those made of rubber.

Cuts from glass constitute the most common laboratory accident, and potentially one of the most dangerous, as the open cut provides a way for toxic chemicals to enter the bloodstream directly. Do not begin any operative of cutting, bending, or inserting glass into a stopper or host without understanding the complete procedure and each separate step.

a) When cutting glass tubing, be sure to hold the tubing firmly, and to make a single steady stoke with a sharp file. When breaking the tubing at the cut, cover the tubing with cloth and hold it in both hands, well away from the body. Push out the tubing but do not deliberately bend the glass with your hands. Wetting the nick will help open the fracture. Be sure that you are well away from others in the laboratory. Be especially careful in cutting a short piece from a long piece of tubing, since the long end may whip around and injure a nearby person.

b) When boring a stopper, be sure the borer is sharp and one size smaller than that which will just slip over the tube to be inserted. In the case of a rubber stopper, lubricate with water, or preferably glycerol or ethylene glycol. Holes should be bored by slicing through the stopper, twisting with moderate forward pressure, grasping the stopper only with the fingers and keeping the hand away from the back of the stopper. Place the stopper on a wooden board or block to avoid damaging the cutting edge of the borer. Keep the index finger of the drilling hand against the barrel of the borer and close to the stopper in order to stop the borer when it breaks through. Preferably drill only part way through, the finish drilling from the other side. Discard a stopper if a hole is irregular or does not fit the inserted tube snugly, if the stopper is cracked, or it if leaks.

c) Stoppers should fit so that 1/3 or 1/2 of the stopper is inserted into the joint. Corks should first be softened by rolling and kneading. With hands close together to minimize being cut in case the vessel breaks, gently but firmly twist the stopper in place. Avoid exerting any pressure on inserted glass tubes. When available, ground glassware is preferable. Glass stoppers and joints should be clean, dry, and lightly lubricated. Stuck glass stoppers can be removed using commercially available bottle stopper remover. Students should ask instructors for assistance when glass connections, stoppers, or corks are stuck.

d) Fire polish all glass tubing, including stirring rods. Unpolished glass has a razor-sharp edge which will not only lacerate the skin, but will cut into a stopper or rubber hose, making it difficult to insert the glass properly. After fire polishing or bending glass, allow ample time for it to cool; grasp it gingerly at first in case it is still hot.

e) To remove a glass tube from a stopper, use a lubricated, dulled cork borer or the tang of a small file, inserted between tube and stopper. Lubricate as separation progresses. Sometimes it may be useful to roll the stopper with a block of wood under enough pressure to flex the rubber. If none of these procedures works, remove the tube by cutting the stopper with a single-edged razor blade. If this is not feasible, discard the stopper and tube.

f) When inserting glass tubing or rods into rubber hoses, fire polish both ends of the glass to be inserted. Lubricate the glass with water, or preferably glycerol or ethylene glycol. Wrap a cloth around the glass and hold it close to the hose (not more than 5 cm). Protect the hand holding the hose with a cloth or glove. Insert the glass into the hose with a slight twisting motion, avoiding too much pressure or torque.

3. Sharps

Handle sharps (razor blades, scalpels, knives, syringe needles) with care. When using a razor blade or knife for cutting, aim the cutting stroke away from your body. Sharps shall not be placed in ordinary waste containers. Rather, they shall be placed in appropriately labeled sharps containers for disposal. If syringe needles are to be recapped or removed, this should be accomplished through the use of a mechanical devise, or a one-handed technique.

4. Microbiological Techniques

a) Wash the hands thoroughly with soap and hot water before beginning any culture work with bacteria or fungi.

b) Minimize all air movement, i.e. close windows, cut off electric fans, etc. while working in the laboratory. Once a gust of wind crosses an open culture, the laboratory may be contaminated for the day.

c) Before beginning culture work of any kind, wipe the work bench off with disinfectant. Again wipe off the bench after completing your work.

d) Sterilize all needles, loops, etc. over a flame before and after using. Generally it is best to rinse the instrument in alcohol before flaming.

e) Contaminated cultures must be autoclaved immediately. NEVER open a contaminated culture in the laboratory.

f) Label all cultures carefully and completely. A date is an important part of each label.

g) Since each species may require a different optional temperature for rapid growth, cultures should be placed in the appropriate incubators. Avoid direct sunlight and extremes of heat and cold when incubating at room temperature.

h) Glassware should be autoclaved at 15 pounds of pressure for 30 minutes or sterilized in a dry oven at 160°C for 2 hours or more. Only borosilicate glassware should be used.

i) Pathogenic organisms must be handled with EXTREME CARE to avoid infection. It must be remembered that these organisms, even though not growing at the expense of living tissues, nevertheless are capable of causing disease. The contents of such cultures should never be poured down the sink or discarded in the waste can, but should be destroyed by autoclaving, by strong disinfectants, by boiling thoroughly for one hour, or by burning.

5. Electricity

Electricity becomes a hazard in the laboratory when the current passes through a person or through a flammable or explosive material. Care with electrical connections, particularly with grounding, and not using frayed electrical cords can reduce such dangers.

Equipment in the laboratory must have grounded (three-prong) plugs or be double insulated. Temporary wiring and the use of extension cords should be avoided. All wiring must meet the National Electric Code specifications. Where wet conditions are likely, ground fault circuit interrupters must be installed. All switches that are not directly and obviously attached to a piece of equipment should be labeled to show the equipment they control; in-line cord switches are discouraged.

If, when you touch a piece of electrical equipment, you feel a shock or "tingle," you should disconnect it and report it for repair immediately. Shorts in circuitry get worse, and delay in reporting greatly increase the hazard. Have it checked by a qualified electrician. Never attempt to repair any electrical equipment with the current on. Equipment that is faulty or broken must be unplugged and moved or taped in such a way that it cannot be accidentally plugged in or turned on. The equipment should be clearly labeled as unsafe and not to be used while awaiting repair.

6. Vacuum Operations

Because of the pressures involved, equipment used in vacuum operations must be carefully inspected frequently and regularly. Apparatus must be assembled so as to avoid strain, and heavy assemblies must be supported from below as well as by the flask neck. Vacuum apparatus should always be placed well back from the edge of the bench top or hood sill, where it will not be accidentally struck. Inspect frequently for signs of fatigue or wear.

a) Shielding

Either standing shields or face shields should be used in all vacuum operations, especially when the apparatus contains flasks of 1 liter or larger.

b) Vacuum Desiccators

Vacuum desiccators should be enclosed in a box or approved shielding device (such as "desigard") for protection in case of an implosion. When opening a desiccator that has been under vacuum, make sure that atmospheric pressure has been completely restored. A "frozen" vacuum desiccator lid can be loosened by a single-edge razor blade inserted as a wedge and then tapped with a wooden block to raise the lid.

c) Water Aspirators for Vacuum

Water aspirators for vacuum are used mainly for filtration purposes; use only equipment that has been approved for this purpose. Never apply a vacuum to a flat bottom flask unless the flask is a heavy-walled filter flask designed for the purpose. Place a trap and a check valve between the aspirator and the apparatus so that water cannot be sucked back into the system if the water pressure should fall unexpectedly while filtering. These recommendations also apply to rotary evaporation operations where water aspirators are being used for vacuum.

d) Vacuum Pumps

A cold trap should be placed between the apparatus and the pump so that volatiles from distillation do not get into the pump oil or out into the atmosphere of the laboratory. Exhausts from pumps should be vented properly. All pumps must also have a belt guard to prevent hands or loose clothing from being pulled into the belt pulley.

e) Vacuum-Manifold and Schlenk Line Safety

Vacuum and Schlenk lines frequently combine vacuum and inert gas manifolds in order to manipulate chemicals without exposure to the atmosphere. In addition, high vacuum lines make possible quantitative measurement and transfer of gases. Most common equipment is constructed of borosilicate glass and either Teflon in glass or greased stop-cocks and thus is used at or below atmospheric pressure. Specifically designed metal lines are used for high pressure or handling of particularly corrosive materials such as fluorine gas. For a detailed description of various types of apparatus, see D.F. Shriver and

M.A Drezdon, Manipulation of Air-Sensitive Compounds, 2nd Edition, New York: Wiley, 1986.

The major safety concerns can be separated into those involving the vacuum system and those related to the inert gas which corresponds to the two manifolds of standard Schlenk lines. In some cases, a “single” Schlenk or inert gas purge line is sufficient for flushing reaction flasks and transferring reagents by syringe to single needle techniques. The major problem with the inert gas line is regulating and controlling the pressure. This can be accomplished by using a gas regulator or more commonly by use of a pressure release “bubbler” containing mineral oil or mercury that is open to the atmosphere. Since mercury is volatile and toxic, it must be vented to a hood and the bubbler should be enclosed so as to prevent a spill of the liquid if breakage occurs. Any large diameter glass bulbs used as “ballast” or which may be evacuated should be taped or otherwise shielded to avoid the hazards of flying glass if explosion or implosion occurs. Care should be taken to secure glassware with clamps, springs or rubber bands to prevent inadvertent launches of stoppers, stopcocks or other projectiles.

Several procedures are imperative for safe operation of a vacuum line. Appropriate shielding of the line in the event of implosion is recommended. Since liquid nitrogen is frequently used as a coolant in traps to prevent escaped of solvent vapors and gases to diffusion and mechanical pumps, care must be taken so as to not collect condensable gases (liquid air) in the trap. Liquid air is a potent oxidant and rapid evaporation can lead to explosion. Leaks in the system can lead to this problem. Dewar flasks should be taped or shielded to prevent flying glass in the case of implosion and care should be taken in filling glass Dewars to avoid cryogenic burns and breakage of the Dewar. Never leave a cold trap in place after the vacuum pump is turned off! Immediately removed the liquid nitrogen Dewar and place the trap in the fume hood for safe removal and proper disposal of its contents. Careful planning of experiments should be carried out to avoid over-pressurization of a vacuum line by expansion of gases. Mercury manometers should be avoided in design of vacuum lines if possible and constructed so as to minimize the amount and possibility for dispersion of Hg into the laboratory.

Whether a vacuum system is under a vacuum of a few Torr, a few millitorr, 10^{-3} Torr, or 10^{-11} Torr, for all practical purposes, the pressure being exerted on the vessel by the atmosphere is the same. Don’t assume that 10^{-3} Torr is less dangerous than 10^{-11} Torr.

One of the biggest dangers associated with working under vacuum is the danger of implosion. When the vacuum vessel is constructed of glass or other shatterable materials, this danger can be extreme. Even stainless steel vacuum systems will occasionally have some component made of glass. Take the necessary precautions like taping the vessel if it doesn’t have to be heated, or work behind a mechanical shield with safety glasses.

Vacuum manifold traps can condense large quantities of material that may not be an explosion hazard based on their chemical reactivity, but which may be an explosion hazard based on their expansion into a closed volume upon warming. Exercise great caution when venting and warming up a system after these kinds of uses. Sorption pumps, for example, can pump extremely large quantities of gas at low temperature. Do not defeat or bypass the built-in safety features of these pumps.

Rough pumps that have been used to pump gases will have some of these gases dissolved in the oil. Some rough pumps will have a means by which to "purge" the oil of these dissolved gases with atmospheric air. Exercise caution when changing the oil in the rough pump, since it will likely contain history of what has been pumped, and the oil may release these gases when vented to atmospheric pressure.

Low pressures and high voltages can combine to create dangerous situations. Pressures in the 10^{-2} to 10^{-4} Torr range with voltages of only a few hundred volts can cause plasma to be excited in the vessel. The plasma may be harmless, but it could cause other problems (unexpected turn-off of pumps and hence, venting of the manifold, ignition of some of the gases, etc.).

The achieving and measuring of vacuum often involves a combination of high voltages and dangerous mechanical motions (e.g. rotary pumps). Cover belts and wheels with guards, and exercise caution so as not to get body parts and clothing caught in these devices; cover exposed high voltage sources.

7. Pressure Operations

As with vacuum operations, the equipment used in high pressure procedures must be regularly and frequently inspected for any signs of wear or fracture. Each pressure vessel should be clearly stamped or labeled with its basic allowable working pressure, the allowable temperature at this pressure, and the material of construction. Always use a pressure relief disk or other suitable devise in pressure systems. The relieving pressure and setting data should be printed on a tag attached to installed pressure-relieving devices, and the setting mechanisms should be sealed.

Before any pressure equipment is altered, repaired, stored, or shipped, it should be carefully vented and cleaned. When attempting such apparatus, avoid strain and excessive force. Threads must match correctly. Never use oil or hydrocarbon-based lubricant on apparatus that will contain oxygen. Kel-F oils or greases (polychlorotrifluoroethylene oils or greases) are the proper lubricants for these systems. In assembling copper tubing, avoid sharp bends and allow flexibility. Check for hardening and cracking in the copper; renew if necessary.

All reactions under pressure must be shielded, and prominent signs should be placed to warn others of high pressure hazard.

8. Heating

a) Open Flame

Wherever possible, use heating mantles, heating tapes, or laboratory hot plans in place of gas (Bunsen) burners. When using a heating mantle, always operate below the maximum allowable voltage for that mantle. It is obvious that open flame must never be used where explosive or flammable chemicals are present, but the presence of such chemicals may be unsuspected or sudden. If a burner must be used, distribute the heat with flame retardant wire gauze, or by moving the burner about underneath the container being heated. Test tubes being heated in this way should be held with a test tube holder at about a 45° angle and heated gently along the side, not at the bottom, to minimize superheating which may cause the contents to be ejected. Avoid pointing a test tube toward yourself or any nearby person.

b) *Hot Plates*

Never heat open containers of flammable materials on hot plates. The heat switch sparks within the hot plate and can ignite flammables.

c) *Open Flame*

Hot oil used for heating purposes is often overlooked as a hazard, yet it carries serious dangers: (1) spattering caused by water falling into hot oil, (2) smoking caused by decomposition of the oil or of organic materials in the oil, and (3) fire caused by overheated oil bursting into flame. Operating baths should not be left unattended unless a high temperature cut-off is installed. Precautions should be taken to contain any spills of hot oil caused by breakage or overturning of the baths. Fiberboard, cardboard, or other combustible components must not be used in heated apparatus.

In evaluating a hot oil bath setup, carefully consider the size and location of the bath, the operating temperature and temperature-control device, the type of oil used (silicone oil is suggested for most heating baths); the bath should include the name of the oil and its safe working temperatures. Silicone oil is a safe, non-flammable fluid which can be used in heating baths to 250°C (about 480°F) without decomposition.

d) *Sand Baths*

Due to the insulating character of sand, a great deal of heat can build up between a hot plate and the sand bath.

i. Do NOT fill the container more than half full of sand

ii. Do NOT turn the heat above 30%.

iii. Do NOT leave the heat on after the bath is no longer being used

e) *Temperature Control*

The rates of all reactions increase as the temperature increases. Highly exothermic reactions may become dangerously violent unless provisions are mode for cooling, for example, by bringing a cooling bath up around a flask. Virtually all reactions require some temperature control, and thus apparatus should be assembled in such a way that either heating or cooling can be quickly applied or withdrawn. A suitable thermometer should be used in a boiling liquid where a strong exothermic reaction is likely so that there will be warning and time to apply cooling.

Boiling stones or boiling sticks should be used in unstirred vessels of boiling liquid (other than test tubes) to prevent superheating and "bumping." Do not reuse boiling stones or sticks. Do not add them or any other solid material to a liquid which is near its boiling point since this is likely to cause splattering or boil over.

9. Cooling

a) *Flowing Water*

When cooling with flowing water, beware of differences in water pressure when operations have to be left unattended for long periods, particularly overnight. In such situations, you may need to use an automatic water regulator installed in the line to keep the flow even, as well as a water flow monitor that will shut down all equipment if the flow is interrupted. Wire all rubber or plastic tubing to metal or glass connections to prevent the tubing from detaching, thus avoiding the risk of a flood.

b) *Cooling Baths*

When ice water is not cool enough as a bath, salt and ice may be used. For even lower temperatures, dry ice may be used with an organic liquid, such as acetone, ethanol, or ethylene glycol. Ethylene glycol, with a flash point of 111°C (230°F), is the best of the three listed above, considering flammability. When choosing a liquid for use with dry ice, you must consider the viscosity, flammability, volatility, solubility in water, and the possibility of toxic vapors.

Few, if any, liquids are free from all of these hazards. Your choice must also be made based on the temperature requirements of your procedure and the limitations of your equipment.

c) *Cryogenics*

Cryogenic experiment setups involve hazards due to extremely low temperatures, and also hazards associated with the high pressure gases that are often part of such setups (see the following section on Compressed Gases). Be careful to control ignition sources and to monitor the formation of very high or very low concentration oxygen.

Safe management of the hazards associated with extremely low temperatures requires thorough understanding of the unique conditions created. For example, the extreme cold of liquid nitrogen can make metals and other materials brittle. Uninsulated equipment can condense oxygen from the air to yield dangerously high concentrations of liquid oxygen, which can explosively ignite many combustibles. On the other hand, liquid nitrogen, left open, reduces the oxygen content of the air as the oxygen condenses and the nitrogen evaporates. A person working in an inadequately vented area could lose consciousness without warning, and will die without rescue. Good ventilation is essential in all cryogenic operations, along with an understanding of the low-temperature behavior of the substance involved.

Contact of liquefied gases with eyes or skin produces serious burns. Damaged tissue should be flooded with a gentle stream of water, not warmer than body temperature (using an eyewash, for example). The affected area should then be dried very gently (excluding eyes) and protected until medical assistance arrives. To avoid contact with liquefied gases, wear goggles, face shield, and insulated gloves that fit loosely enough to throw off in case of a spill. The body should be completely covered, with no skin exposed. Wear no jewelry, and avoid clothing with cuffs or pockets that could trap and hold a cryogenic liquid close to the skin.

Put objects into a cryogenic liquid slowly, and pour liquids into containers lowly in order to minimize the inevitable boiling and splashing.

For the same reason, dry ice should be added to liquid slowing and in small amounts, to avoid foaming and boil over. Handle dry ice with dry leather or insulated gloves, and never lower you head into a dry ice chest, as the oxygen content may be inadequate and suffocation can result.

Dewar flasks and cold traps should be taped to prevent flying glass in case of breakage. Avoid pouring cold liquid over the edge of a Dewar flask, as it may break and implode.

10. Compressed Gases

Gases are supplied in cylinders under great pressures, some as much as several thousand pounds per square inch. If the valve is broken off at the cylinder neck, the cylinder becomes a potentially deadly rocket, propelled with great momentum and high speed. Gas cylinders have been documented to cause extensive property damage, injury, and death. For this reason, all gas cylinders, full or empty, must always be strapped or chained to a sturdy support to prevent the cylinder from falling and breaking off the valve. All cylinders of compressed gas should be treated as high energy sources and therefore regarded as potential explosives.

In addition, released gas can rapidly displace the breathing air in a room, causing suffocation. Many gases are toxic or corrosive and can cause injury if inhaled or contacted in even small amounts. Many gases are reactive with other materials or gases. Oxygen, in greater than normal concentrations, greatly increases the risk of fire and explosion.

Compressed gas cylinders have certain safety features, including special valves, fittings, and caps. For example, many gases have special valves that prevent the inadvertent mixing of incompatible gases. The best protection, though, lies in following the guidelines developed over years of experience with the hazards of compressed gas.

a) Use

Begin with thorough knowledge of the substance and equipment involved. Always know the identity of the gas in a cylinder; if for some reason a cylinder is unlabeled, return it to the vendor; do not guess. Know the properties and potential of the gas to be used, and the procedures for using it. Be careful not to exceed the design pressure of the apparatus. Always wear safety goggles when handling or using compressed gases.

Carefully inspect fittings, regulators, and apparatus for damage before using. Do not use damaged equipment. Use only regulators, gauges, and connections with matching threads and which are designed to be sued with the gas and cylinders involved. Never lubricate, modify, force or tamper with a cylinder valve.

Only those tools approved by the cylinder vendor should be used on cylinder connections. Do not modify or alter cylinders or their attachments. Use cylinders and manifold systems only with their appropriate pressure regulators.

Use cylinders only in well ventilated areas. Corrosive gases should be used only in locations with access to safety showers and eyewash stations. Corrosive, toxic, and flammable gases should be used only in fume hoods designed for use with the particular gas or group of gases. Use flammable gases only after proper bonding and grounding connections have been made.

Do not expose cylinders to temperatures higher than about 50°C (122°F). Some rupture devices on cylinders will release at about 65°C (149°F). Some small cylinders, including those not fitted with rupture devices, may explode if exposed to high temperatures.

Before opening the cylinder valve double check that the pressure knob on the second stage of the regulator is released (turned counterclockwise until it turns freely). Open the cylinder valve slowly about one full turn. Turn the second stage knob until the desired pressure is obtained. Never direct high pressure gases at a person, or use compressed gas or compressed air to blow away dust or dirt; resultant flying particles can be dangerous. Close cylinder and bench valves when the cylinder is not in use and release the pressure in the second stage; the pressure regulator is not sufficiently strong to assure safe closure.

Do not extinguish a flame involving a highly combustible gas until the source of the gas has been shut off. Otherwise, it can re-ignite, causing an explosion.

Always use a trap to prevent back siphonage of liquid chemicals, and a check valve to prevent back flow of gases into the cylinder. When gas is passed from a cylinder into a vessel containing a liquid, contamination of the cylinder gas with other chemicals is a real possibility. Such contamination makes the gas unsuitable for future use and may result in explosion with resultant injury, damage, or even death. Use of a safety trap to contain liquid and a check valve to prevent back flow of gas will eliminate this possibility. These are installed immediately after the pressure regulator, and before the vessel containing the liquid. The safety trap should have a volume of about 1.5x the total liquid volume in the system.

Never bleed a cylinder completely empty. Always leave a residual pressure (about 25 psi) to keep contaminants out. Promptly remove the regulators from empty cylinders, being sure to bleed the gas from the regulator first. Replace the protective caps at once. Mark the cylinder “EMPTY” in removable printing. Never refill a cylinder.

b) Used Cylinders

Handle used cylinders as you would full cylinders. Keep them strapped or chained at all times. Store the used cylinders separately from full cylinders so there is no chance of confusing them. Mark all cylinders “EMPTY” in removable writing (such as chalk or an affixed note), or tear the attached tag to indicate empty.

c) Leaking Cylinders

Cylinders that are leaking or otherwise damaged are an immediate danger. If they can be transported safely, they should be taken to an open place separate from all other cylinders to await vendor pickup.

Be very careful, however, when moving any cylinder that is leaking. Avoid inhaling gases while carrying or loading such a cylinder, and try to avoid spreading gases in corridors and stairwells. In the case of toxic or flammable gases, call 911 for help.

d) Transportation

Do not move a cylinder unless the cap is in place.

Generally, cylinders must be transported on a hand truck to which they can be strapped or chained. Cylinders may be rolled on edge only for very short distances. Use an elevator, if possible, to move cylinders to upper or lower floors. When using an elevator, however, avoid riding with non-empty cylinders. Rather, send the cylinder to the desired floor and take the stairs to meet it there. If stairs must be used, move cylinders on a hand truck which is equipped for stairs.

When handling cylinders, always consider them to be full. Do not allow them to strike each other, or to be dropped, cut, scraped, or otherwise damaged.

e) Storage

Keep only those cylinders currently in use in the laboratory. All cylinders, in use or in storage, must be secured to a sturdy object, such as a wall, bench or stand, using a strong strap or chain.

Store full and used (empty) cylinders only in isolated areas that are ventilated and protected from direct sunlight, rain, snow, damp ground, heat, fire, and electrical contact. Temperatures in storage should be maintained between -20°F and 120°F unless the manufacturer indicates otherwise. Storage can be indoors or outdoors under a shelter. Never store or use cylinders in corridors, stairwells, or in high traffic areas.

Cylinders of the same gas should be stored together. Oxidizers should be separated from flammables and combustibles by twenty (20) feet of space, or by a one-hour rated firewall and five (5) feet of space. In addition, store used (empty) and full cylinders separately and clearly indicate whether they are full or empty.

Keep caps on all cylinders except when connected for use, and keep cylinders upright, whether in use or storage.

11. Laser Safety

It is imperative that personnel not look directly into ANY laser while it is in operation. Wavelengths of 200-315nm are absorbed by the cornea of the eye (causing "welders flash"), whereas wavelengths of 315-400nm are absorbed by the lens and iris of the eye, and wavelengths of 400-1400nm pass through the ocular media of the eye and damage or burn the retina. Helium-Neon lasers are common and often used carelessly. It is emphasized that even low power (5-10 mW continuous output) He-Ne lasers or low-energy pulsed lasers can cause eye damage. High-energy pulsed lasers are those with beam energies of 50 joules or more; typical wavelengths are 4880 Å to 5145 Å, 10,600 Å, and 106,000 Å.

Eye protection for use with laser beams requires goggles that have sufficient protective material and are fitted so that even stray laser beams cannot enter they eye obliquely. This is especially important for high-energy or high power laser work. Protection from three of the most common lasers assumes the following form:

Ar-ion laser: Protective glasses and screens of amber plexiglass or ruby-tinted plastic effectively protect the eyes against the output of an Ar-ion laser.

CO_2 laser: This laser generates an invisible beam and is extremely dangerous. Hands and clothing must be kept out of the target area. 2mm thick fused-quartz plates can protect personnel against eye damage.

He-Ne laser: BG-18 glass effectively filters out the 632.8nm output beam from this laser. While the IR wavelengths generated by this laser are of low energy, sufficiently large doses can cause eye damage.

Lasers users must be particularly careful about reflections of laser beams. Specular reflections (from mirrors and other polished, flat surfaces) pose the greatest damage to the eye due to the collimated nature of the beams. Distance offers no protection from specularly reflected laser beams. Example: a modest pulsed dye laser (pumped by a Nd:YAG laser) puts out 25mJ per pulse. An air/glass or air/quartz interface, like that of a solution cell, reflects about 4% of the radiation, or about 1mJ. That is 2000 times the damage threshold! Diffuse reflections, from rough surfaces, are less damaging, but can also pose risk.

Users and support staff should be aware that working conditions must be in compliance with ANSI Z136.1-1993, the American National Standard for Safe Use of Lasers. In the lab area, warning signs are required. There should be no unauthorized access to a laser lab (e.g. custodians, unescorted guests).

A laser lab should contain no student desks or low work tables where eye-level exposure is a risk. The laser area should be separate from other experimental areas through the use of curtains or partitions.

When doing laser experiments:

a) Propagate the beam at a low height just above (and parallel to) the table top

b) Avoid eye-level contact with the beam or reflections

c) Use low laser power to align new experiments (attenuate with a filter or reduce the supply current

d) Laser safety goggles or glasses are the rule for near IR, UV and high-powered pulsed lasers

e) Keep reminding yourself that specular reflections (from metal surfaces, filters, beam splitters, sample cell windows, lenses) are a hazard. Chase down stray beams under low-power alignment conditions. Enclose the beam in a conduit whenever possible.

Laser electrical hazards: the only life-threatening hazard of lasers is from the power supply. Most lasers have high-voltage DC power supplies capable of delivering lethal amounts of current. A high-voltage capacitor in a laser power supply charged up to 10,000V could lead to peak currents through the boat of 20amps (20,000mA). It has been shown that 50mA of current, at an appropriate frequency, is enough to send the heart into ventricular fibrillation. So, always disconnect the power cord before servicing a power supply. Use a grounding stick to bleed off any charge from capacitors before doing any work. Check the presence of residual voltages, one handed, with a multimeter.

F. Handling Chemicals

Following are guidelines and principles for safety in the direct manipulation of chemicals—holding, pouring, mixing, transporting, storing, and so on. The list of situations covered is far from exhaustive; emphasis is instead on the most common ways in which chemicals are handled in the laboratory. Safety precautions for use of laboratory equipment can be found in Safety Systems (Section C) and General Laboratory Equipment Setup (Section E).

1. Personal Contact

The primary safety goal in handling chemicals is to prevent the chemicals from entering your body. It cannot be said too often that protective gear must be worn at all times, and precautions for avoiding personal contact with the chemicals must always be in mind.

a) Avoid direct contact of any chemical to the hands, face, and clothing. Be aware of what you touch; be careful not to touch gloves to your face, for example. After any skin contact, and always before you leave the laboratory, wash face, hands and arms. Leave all equipment in the laboratory.

b) Never taste chemicals or sniff from chemicals containers.

c) Never eat, drink, smoke, or apply cosmetics in the laboratory.

d) Dispense and handle hazardous materials only in areas where there is adequate ventilation.

e) If you believe that significant ingestion, inhalation, injection, or skin contact has occurred, call emergency services (campus security and/or 911) and follow the Emergency Procedures given earlier in this guide.

2. Handling Containers

Clearly label all chemical containers. The Laboratory Standard requires that labels on incoming chemical containers not be removed or defaced. Do not use any substance from an unlabeled or improperly labeled container. Printed labels that have been partially obliterated or scratched over, or crudely labeled by hand, should be relabeled properly. Unlabeled chemical containers are a hazard and should be disposed of promptly and properly.

Carefully read the label before removing a chemical from its container. Read it again as you promptly recap the container and return it to its proper place. Names of distinctly different substances are sometimes nearly alike; mistakes are easy to make and can be disastrous.

When picking up a bottle, first check the label for discoloration, and if it is clean, grasp it by the label. Spilled chemicals will show up on the label better than on the glass; holding the container by the label will protect you from prior spills, and protect the label from present ones. After use, wipe the bottle clean.

If a stopper or lid is stuck, use extreme caution in opening the bottle. Friction caused by removing tops may cause explosions with some substances (such as hydroperoxides formed from ethers or picric acid contaminated with heavy metals).

Support beakers by holding them around the side with one hand. If the beaker is 500mL or larger, support it from the bottom with the other hand. IF the beaker is hot, use beaker forceps or tongs, and place the beaker on a heat-resistant pad.

Grasp flasks by the center neck, never by a side arm. If the flask is round bottomed, it should rest on a properly sized cork ring with it is not clamps as part of a reaction or distillation assembly. Large flasks (greater than 1000mL) must be supported at the base during use.

Never look down the opening of a vessel, in case of unforeseen volatility or reaction.

3. Pouring

Do not pour toward yourself when adding liquids or powders. Stoppers too small to stand upside-down on the bench should be held at the base and outward between two fingers of the pouring hand.

Use a funnel if the opening being poured into is small. If a solid material will not pour out, be careful when inserting anything into the bottle to assist removal. Student should seek advice from instructors before proceeding.

Always add a reagent slowly; do not “dump” it in. Observe what takes place when the first small amount is added and wait a few moments before adding more.

When combining solutions, always pour the more concentrated solution into the less concentrated solution or water. Strive to avoid violent reactions and splattering. The more concentrated solution is usually heavier and any heat evolved with be better distributed. This procedure is particularly applicable in preparing dilute acid solutions. Be sure to wear goggles and use the hood when diluting solutions.

Make sure the stopcock is closed and has been freshly lubricated before pouring a liquid into an addition or separatory funnel. Use a stirring rode to direct the flow of the liquid being poured. Keep a beaker under the funnel in the event the stopcock opens unexpectedly.

Wear an apron and gloves, in addition to goggles, whenever pouring bromine, hydrofluoric acid, or other very corrosive chemicals, to avoid painful chemical burns.

4. Pipetting

NEVER pipet by mouth. Use an aspirator bulb, or another mechanical Pipetting devise. Constantly watch the tip of the pipet and do not allow it to draw air. Use micropipettors at eye level.

5. Storage

Keep as few chemicals as possible on the bench-top. All chemicals not immediately needed should be properly stored.

Do not store incompatible materials together or in close proximity. The best segregation scheme is as follows:

Class 1 – Flammable or combustible and compatible with water
Class 2 – Flammable or combustible and incompatible with water
Class 3 – Oxidizers and non-flammables, compatible with water

Class 4 – Oxidizers and non-flammables, incompatible with water
Class 5 – Air sensitive
Class 6 – Chemicals requiring refrigeration
Class 7 – Compressed gas cylinders, separated as to oxidizers, reducers, corrosives, toxics
Class 8 – Unstable chemicals (explosives)

Use safety cans with flame arrestors for quantities of flammable solvent larger than 4 liters, and be sure to leave a space at the top of a closed container for expansion of liquid and vapors. If chemical purity requirements preclude metal containers, glass containers may be used. Containers no larger than one pint (500mL) should be used to store NFPA Class IA liquids, including but not limited to: acetaldehyde, diethyl either, ethyl chloride, methyl formate, low-boiling petroleum ether, pentane, and propylene oxide.

Store large containers of reagents on low shelves, preferably in a tray adequate to contain spills or leakage.

Dispense corrosive liquids in small containers, no larger than 500mL, preferably in chemically-resistant coated containers. Never take more than is immediately needed.

a) Refrigerators

Ordinary household refrigerators constitute a hazard when used for storage of flammable or unstable chemicals. These units produce conditions which can lead to explosion. Domestic (household-type) refrigerators may not be used for flammable chemical storage unless suitably modified to eliminate all possible contact between vapors and electric spark or arcing. Explosion-proof refrigerators are preferred.

When searching for an item in a refrigerator used for chemical storage, be careful not to inhale vapors that may have built up in the cabinet.

All chemicals, including those stored in refrigerators, should be sealed and labeled with the name of the material, the date it was placed in storage, and the name of the person storing it there. Refrigerators should be cleaned on a regular schedule, and old chemicals should be properly discarded.

Food must NEVER be stored in any refrigerator used to store chemicals.

b) Storage of Flammable Chemicals – Containers

Keep flammables in use in the laboratory in safety cans specifically designed for that purpose at all times. In the event that such cans are not available, glass bottles may be used with the proper precaution. The containers used by the manufacturer must meet certain standards for shipping. These same containers are not always suitable for routine use. The shipping container must be sealable and of suitable shape and strength for transport. This transport is usually within another container—carton, crate, etc. Do not use screw caps to close bottles containing volatiles (such as diethyl ether, low-boiling petroleum ether, methylene chloride and pentane) as pressure build-up can cause failure in a bottle which is not new and which may have internal strains which come from normal use. In such situations, use corks or neoprene stoppers. Use a one-holed cork fitted with a drying tube if moisture must be excluded. To relieve pressure build-up, use a cork fitted with a check valve. Keep all flammables away from direct sunlight and sources of heat.

Storage of Flammable Liquids
Maximum Allowable Container Capacity (NFPA) 45.7*

	Flammable Liquids			Combustible Liquids	
Container Type	IA	IB	IC	II	III
Glass or approved plastic	1 pt	1 qt	1 gal	1 gal	5 gal
Metal (other than DOT drums	1 gal	5 gal	5 gal	5 gal	5 gal
Safety Cans	2 gal	5 gal	5 gal	5 gal	5 gal
Metal Drums (DOT spec.)	5 gal	5 gal	60 gal	60 gal	60 gal

In instructional laboratory work areas, no container for Class I or II liquids shall exceed a capacity of 1 gallon, except that safety cans may be of 2 gallon capacity.

*Exception: Glass containers as large as 4L may be used if needed and if the required purity would be adversely affected by storage in a metal or an approved plastic container, or if the liquid would cause excessive corrosion or degradation of a metal or approved plastic container.

c) *Flammable Storage Cabinets*

Only one (1) storage cabinet may be located in a laboratory. Cabinets shall be labeled in conspicuous lettering: “FLAMMABLE – KEEP FIRE AWAY.”

Flammable storage cabinets are designed to protect the contents from external fires. For this reason, the door(s) must be kept closed except when removing or replacing the cabinet’s contents. These cabinets do not necessarily protect people from solvent vapors during normal use of the cabinet. There are vent kits available for flammable storage cabinets; however these cabinets are fire tested with the vent holes closed. The NFPA Flammable & Combustible Liquids Code Handbook recommends against venting these cabinets as this practice may defeat the designed purpose. Where particularly noxious or toxic chemicals are being used, cabinets may be vented, with prior approval.

The interior of the cabinet is capable of withstanding the effects of vapors from solvents, but not of other materials such as corrosives. As these materials are incompatible with most flammables, only flammable storage cabinets are designed with a lip to contain a two-inch depth of a spilled liquid.

d) *Storage of Acids*

Acid storage cabinets are designed to withstand corrosion, contain spills, keep like materials together, and protect the contents from physical damage. If ordinary cabinets used for acid storage show signs of deterioration, consider relocating the acids to a specially-designed cabinet. As acids are incompatible with alkalis, flammables, and other classes of chemicals, only acids may be stored in these cabinets.

Dichromate cleaning solution is an unsuspected source of pressure build-up explosions in the laboratory. Although the storage of this common cleaning solution in the glass shipping container is a common laboratory practice, it has led to several serious incidents. Occasionally, the dichromate solution will contain sufficient amount of organic material from previous glass cleanings to evolve a large enough quantity of carbon dioxide to explosively rupture a screw-topped glass bottle. To prevent a possible explosion, and subsequent potential injury, a stopper is recommended. See the recommendations given above for storage of flammables.

6. Chemical Inventories

A chemical inventory list must be prepared, maintained, and updated with all chemicals present in the laboratory. This list should include, for each container, the chemical name(s) of the contents, the CAS Number (Chemical Abstracts Service Number), the quantity and the container type. This list is also useful for acquiring the MSDSs needed and to carry out work both safely and in compliance with the OSHA standards. For example, identification of a substance as a Particularly Hazardous Substance and a carcinogen and taking the appropriate precaution in its use, would not be possible without compiling the list.

In the case of shared spaces, information on chemicals present should be provided by a user to another user, upon request.

7. Transportation

Bottles of one gallon or more should be transported in bottle carriers that could completely contain the substance in the event of breakage. This is particularly important in transporting corrosive, toxic, or flammable liquids. If you need to move several such containers at once within a building, use bottle carriers and a properly designed cart. All containers should be tightly capped during transport.

Smaller bottles can be carried by their handles, or by grasping the label and placing the little finger under the base of the bottle. Never try to balance a bottle by holding it solely from underneath. Approach all doors with caution.

If you do drop and break a container, you have the responsibility of calling the emergency number to report the spill and to request assistance in cleanup. Call emergency dispatch 911.

G. Chemical Hazards

This section contains description of the general categories of chemical hazard, and the principles of safety associated with each. This section purposefully does not contain advice for handling specific chemicals. Safe work in a chemical laboratory requires very detailed knowledge of the nature, potential, and compatibilities of each substance used. Anyone planning an experiment or procedure should acquire and review a Material Safety Data Sheet (MSDS) for each substance, and also for all likely products and byproducts. An MSDS for each chemical present in the laboratory is available in the laboratory or department stockroom.

The following categories provide a structure for thinking about—and planning protection against—common chemical hazards. In actual practice, such hazards do not group themselves in neat categories, but usually occur in combination and/or sequence. The categories and concepts are provided as an aid to awareness, and as encouragement for consistent safe planning and practice.

1. Flammability

Flammability is one of the most common chemical hazards. The exact degree of hazard, however, depends on the specific substance and the conditions you expect to use it in. To handle a flammable substance safely, you must know its flammability characteristics: flash point, upper and lower limits of flammability, and ignition requirements. This information appears on each MSDS.

a) Flash Point

For a liquid, the flash point is the lowest temperature at which the liquid gives off enough vapor to form an ignitable mixture with air and produce a flame when a source of ignition is present. Many common laboratory solvents and chemicals have flash points that are lowers than room temperature.

b) Ignition Temperatures

The ignition (or autoignition) temperature of a substance—solid, liquid, or gas—is the minimum temperature required to initiate self-sustained combustion. Some ignition temperatures can be quite low. For example, carbon disulfide ignites at 90°C (194°F).

c) Autoignition

Autoignition or spontaneous combustion occurs when a substance reaches its ignition temperature without the application of external heat. This characteristic is particularly important to keep in mind in the storage and disposal of chemicals.

d) Limits of Flammability

Each flammable gas and liquid (as a vapor) has a limited range of flammable concentration in mixtures with air. The lower flammable limit (or lower explosive limit) is the minimum concentration below which a flame is not propagated when an ignition source is present—such a mixture would be too lean to burn. The upper flammable limit (or upper explosive limit) is the maximum concentration of vapor in air above which a flame is not propagated—such a mixture is too rich. The flammable range (or explosive range) lies between the two limits.

Listed measurements of all these characteristics—flash points, ignition temperatures, limits of flammability—are derived through tests conducted under uniform and standard conditions that may be very different from actual practice. For example, concentrations of vapor in air in a laboratory are rarely uniform, and point concentrations can be quite high. It is good practice to set maximum allowable concentrations at 20% of the listed lower limit of flammability within closed systems. (It is important to note that, generally, this 20% limitation is still well above the maximum concentration considered to be safe for health considerations.)

e) Precautions with Flammable Liquids

Flammable liquids do not burn; their vapors do. For a fire to occur there must be 1) a concentration of vapor between the lower and upper flammable limits, 2) an oxidizing atmosphere, usually air, and 3) a source of ignition. As it is unlikely that air can be excluded, the unrealistic (given the constant possibility of a spill) to assume that the vapor concentrations can be controlled, the primary safety principle for dealing with flammable liquids is strict control of ignition sources.

Ignition sources include electrical equipment, open flames, static electricity, and, in some cases, hot surfaces. Others working in the laboratory should be informed of the presence of flammable substances so that ignition sources can be eliminated. Obviously, it is very important to know which of those sources is capable of igniting a substance you are using.

Remember that most flammable vapors are heavier than air, and will spread out horizontally for considerable distances until an ignition source is contacted.

If possible, flammable liquids should be handled only in areas free of ignition sources. Heating should be limited to water and oil baths, heating mantles, and heating tapes.

Static-generated sparks can be sudden ignition sources. When transferring flammable liquids in metal equipment, take care that metal lines and vessels are bonded together and grounded to a common ground.

Ventilation is very important. A fume hood should be used when flammable liquids are allowed to stand in open containers or are handled in any way.

f) Precautions with Flammable Gases

Leakage of compressed or liquefied gases can quickly produce a flammable or explosive atmosphere in the laboratory. This is obviously true where the gases themselves are flammable and under high pressure, but may also be true in the use of non-pressurized liquefied gases. For example, even relatively safe liquefied gases such as liquid air or liquid nitrogen, if kept in open vessels too long, will generate concentrations of liquid oxygen which can contribute to an explosion. Proper care with compressed gas cylinders and cryogenic setups is essential (see General Laboratory Equipment Setup, Section E).

2. Explosiveness

Ignition of flammable vapors or gases can occur with such speed that an explosion results. There are other substances that are explosive in of themselves—in response to heat, mechanical shock, or contact with a catalyst. With some substances, very tiny amounts of impurity are sufficient to begin a reaction that quickly become explosive.

a) Precautions

Acquire a Material Safety Data Sheet (MSDS) for each chemical you are using. It is crucial that you know its potential including its compatibilities with other substances.

Be alert to any unusual change in the appearance of a reaction mixture. Rapid unexpected temperature rise or fuming are signals for emergency measures such as removing the heat source, quickly applying a cooling bath, or leaving the room.

Explosive compounds should be protected from the conditions to which they are sensitive (mechanical shock, heat, light, etc.). Check your MSDS to see what those conditions are. Such substances should be brought to the laboratory only as required, and only in the smallest quantities absolutely necessary. Reactions involving or producing explosives should be designed on as small a scale as possible, and should be done behind a suitable barricade.

Special care should be taken that equipment is maintained (for example, that oil is routinely changed in vacuum pumps) and that heating methods used do not cause, or increase, the potential for ignition.

Other laboratory workers must be notified when an explosive hazard is present, through direct announcement and conspicuous warning signs.

Highly exothermic or potentially explosive reactions must never be left unattended.

b) *Personal Protection*

In addition to protection otherwise required in the laboratory, wear face shields and heavy gloves at all times when handling known explosive substances. Laboratory coats of a flame-resistant material or treatment may help reduce minor injuries from flying glass or flash. When serious explosive hazard is anticipated, shields and barricades will be necessary, along with devices for manipulating equipment at a safe distance such as long-handled tongs, stopcock turners, mechanical arms, etc.

3. Toxicity

Toxicity is the potential of a substance to cause injury by direct chemical action with the body tissues. Whether the effect is acute or chronic, the only way to avoid such injury is to prevent or greatly minimize contact between toxic chemicals and body tissue.

a) *Measurement*

The dose, or amount of chemical, you are exposed to determines the body's response. In the workplace, there are certain guidelines or regulations which limit your exposure to hazardous substances. These guidelines, which are set by various regulatory or professional organizations, are referred to as "workplace exposure limits."

A workplace exposure limit is the airborne concentration of a material below which most persons can be exposed for long periods of time without adverse effect. These limits are based on an 8-hour time weighted average (TWA) over a working lifetime. Permissible Exposure Limits (PELs) are those set by OSHA. Workplace exposure limits may be expressed as Threshold Limit Values (TLV) or Workplace Environmental Exposure Limits (WEEL).

Time Weighted Average (TWA) is the average concentration of a substance integrated over a period of time (e.g. a normal 8-hour workday).

Short Term Exposure Limit (STEL) is the maximum concentration limit for a continuous 15 minute exposure period, provided that the daily TWA is not exceeded. Because workplace exposure limits are generally expressed as average concentrations, excursions above these values are permitted. The exposure levels during such excursions must be below the STEL. However, there are certain levels which must never be exceeded even instantaneously. These are known as the ceiling levels for a TLV, or TLV-C.

All these measurements, though often based on data from animal research, refer to the exposure and resistance of a healthy adult. These levels do not necessarily apply to pregnant women, their unborn fetuses, or adults who are ill or under special stress. In such situations, the individual and his/her supervisor or instructor must carefully consider all pertinent information.

b) *Acute Toxicity*

Acute toxic effects are usually produced by a single large dose, generally well above the TLV, received in a short period of time. The effects are immediate, and may be partially or totally reversible. Acute toxic effects include

i. Simple Asphyxiation: the body does not receive enough oxygen (for example, when gaseous nitrogen has displaced the air in a room).

ii. Chemical Asphyxiation: the body is prevented from using oxygen (for example, when carbon monoxide instead of oxygen is absorbed in the blood).

iii. Anesthetic: cause dizziness, drowsiness, headaches, and coma (for example, by the vapors of many organic solvents).

iv. Neurotoxic: the brain's control of the nervous system is slowed down or changed (for example, by concentration of lead or mercury).

v. Corrosive: body tissue is directly damaged by reaction with chemicals (for example, by strong acids or bases; see separate subtopic below).

vi. Allergic: repeated exposure to a chemical produces sensitizing, until there is an allergic reaction at the contact site (usually skin).

c) *Chronic Toxicity*

Chronic toxicity refers to adverse or injurious effects that can result from prolonged exposure to a substance, sometimes at dose levels just above the TLV. Damage may not appear for many years—perhaps generations—and is often irreversible. As a result, this class of hazard is both very difficult and very important to guard against. The body can filter and process levels of toxicity that might seem surprisingly high, but over extended periods of time, even with the dose very low, the filtering process may fail, and damage may occur.

Types of chronic toxic effects include:

i. Carcinogenicity: produces cancer (for example, asbestos and vinyl chloride are known to produce cancer in humans).

ii. Mutagenicity: alters cell genes with subsequent generations showing genetic damage.

iii. Teratogenicity: harms developing fetus.

iv. Reproductive toxicity: interferes with the reproductive system in men or women.

v. Specific Organ Toxicity: damages specific organs (for example, carbon tetrachloride can cause liver damage).

d) *Animal Work with Chemicals of High Chronic Toxicity*

i. Access: For large scale studies, special facilities with restricted access are preferable.

ii. Administration of the toxic substance: When possible, administer the substance by injection or force-feeding instead of in the diet. If administration is in the diet, use a caging system under negative pressure or under laminar air flow directed toward HEPA filters.

iii. Aerosol suppression: Devise procedures which minimize formation and dispersal of contaminated aerosols, including those from food, urine, and feces (e.g. use HEPA filtered, vacuum equipment for cleaning, moisten contaminated bedding before removal from the cage, and mix diets in closed containers in a hood).

iv. Personal protection: When working in the animal room, wear plastic or rubber gloves, fully buttoned laboratory coat or jumpsuit and, if needed because of incomplete suppression of aerosols, other apparel and equipment (shoe and head coverings, respirator).

v. Waste disposal: Dispose of contaminated animal tissues and excreta by incineration if the available incinerator can convert the contaminant to non-toxic products; otherwise, package the waste appropriately for burial in an EPA-approved site.

e) *Precautions*

The precautions to take against contact with toxic substances are repeated many times throughout this Plan. With chemicals of low acute toxicity, it may be tempting to be less rigorous; yet it is precisely those chemicals which most require continual caution—an unvarying habit of safety.

You must protect your body against all forms of chemical contact: absorption, inhalation, ingestion, and injection. Never eat, drink or smoke in the laboratory; wear the appropriate protective gear, and always remove it before you leave the laboratory. Make sure you carefully wash your hands before leaving the laboratory. Remember that the chemicals you bring home on your close with have a more powerful effect on growing children and elderly people than on most adults

In order to know what level of personal protection will be adequate, keep up to date on recent tests for substances you are using. MSDSs are updated regularly, and you should consult the most recent data each time you begin a new procedure. The best precaution is to treat all chemicals as toxic.

4. Corrosives

Corrosiveness is a form of acute toxicity sufficiently common and hazardous to merit separate discussion. Corrosive chemicals include strong acids, strong bases, oxidizing agents, and dehydrating agents. When they come in contact with skin, eyes, or, through inhalation, the surface tissues of the respiratory tract, they react with the tissues they touch and cause local injury.

a) Liquid Corrosives

A liquid corrosive will act on the skin rapidly or slowly depending on the concentration and length of contact. These chemicals react directly with the skin: dissolving or abstracting from it some essential components; denaturing the proteins of the skin; or disrupting the skin cells. Mineral acids, organic acids, and bases are among the typical liquid corrosives.

When handling liquid corrosives, contact with them must be scrupulously avoided. Wear goggles, rubber or suitable synthetic gloves, and a face shield. A rubber or synthetic apron and rubber boots may also be necessary. Since many liquid corrosives also release irritating vapors, procedures using these materials should be performed in a fume hood.

b) Solid Corrosives

Solid corrosives interact with the skin or other surfaces when dissolved by the moisture there. Damage then occurs both from the corrosive action and from the heat of the solution. Because they are solid, these chemicals are relatively easy to remove; but because they may not react immediately and may not be painful at first (as with caustic alkalis), they may cause much damage before being detected.

Solid corrosives are most commonly dangerous in a finely divided state. Dust control and good exhaust ventilation are essential, as well as goggles, gloves, and other protective clothing. In case of chemical contact, much care must be taken during the emergency shower irrigation to remove all particles of solid matter that might be lodged in the skin or clothes.

c) Gaseous Corrosives

Gaseous corrosives pose the most serious health hazard of all corrosives because of possible damage to the lungs, including spasms, edema, pneumonia, and even death. Different corrosives affect different parts of the lung (for example, ammonia affects the upper respiratory tract, while phosgene affects the lung, causing pulmonary edema), but all are to be avoided.

It is thus crucial that corrosive gases not be inhaled. Careful design and the use of fume hoods are essential. Skin and eyes must also be protected, as gases contact all exposed parts of the body.

5. Impurities and Combinations

MSDSs contain information on pure chemicals, known mixtures, and proprietary materials—unfortunately there are no such sheets for other materials found in the laboratory, including solutions, mixtures or unknown or uncertain composition, and byproducts of reactions, all common in the laboratory. Impurities, synergistic effects, formation of unexpected products and byproducts, insufficiently clean equipment, and the combination of vapors from your experiment with your neighbor's can all produce sudden and unanticipated hazards.

There are no absolute protections against all contingencies, but it helps to wear protective gear, to clean equipment scrupulously, to be aware of experiments in progress in nearby areas, and to be completely familiar with emergency procedures.

H. Cleanup and Waste Disposal

1. Cleanup

Cleaning up should be a continual process, performed during as well as after an experimental procedure. Cleaning should include yourself and your clothing, laboratory surfaces, equipment, and containers. Wash hands frequently while working in the laboratory; when you leave, remove protective gear and inspect clothing. Care with gear and clothing will prevent taking chemicals home with you; care with equipment and containers will help avoid future contamination and surprise mixtures. Such care requires planning as well as good housekeeping. Cleanup and disposal methods should be part of your written procedures.

When washing glassware, work with a few items at a time, and allow them to drain where they will not fall over. If anything falls, let it fall rather than risk severe cuts by grabbing it as it breaks. If glass has broken into a sink containing water, drain the water and then use gloves when picking out broken pieces. Clean vessels or equipment with appropriate materials (water, soap, acid, etc.). Do not proceed unless you are sure which materials to use; check the MSDS or other references for advice on proper cleaning materials to use with the specific substances to be cleaned up. Follow directions carefully.

2. Waste Disposal

a) Laboratory Glass

Place all glass, intact as well as broken, into a specially marked rigid container designed for this purpose. Rinse all empty hazardous chemical containers three times with small amounts of a suitable solvent or appropriate detergent solution (triple-rinsing) before discarding.

Do not put glass originating in the laboratory into a recycling container.

b) Chemical Disposal

For planned experiments, chemical waste bottles will be made available. For independent projects, determine what chemicals will need to be contained for hazardous waste disposal. Obtain an appropriately sized waste container and label it with:

i. "Hazardous Waste"

ii. Name of the chemical(s)

iii. Hazard classification: toxic, corrosive, reactive, flammable

Keep the container well sealed and segregated from work space

Indiscriminate disposal by pouring waste chemicals down the drain or adding them to mixed refuse for landfill burial is unacceptable. Hoods should not be used as a means of disposal for volatile chemicals. Disposal by recycling or chemical decontamination should be used when possible.

c) Pathogen Disposal

All organisms are to be autoclaved at 15# for 30 minutes before disposal.