GENERAL SAFETY AND LABORATORY PROCEDURES

The objectives of this section are to provide general information on procedures to be used in the laboratory so that the students may perform experiments safely, use proper procedures in handling and disposing of hazardous materials, comply with safety regulations, and be prepared for handling any emergency situations. Your grade in this course will depend in part on your observance of these procedures. While it is the responsibility of the University to maintain safe laboratories and to inform you of the safety procedures and emergency equipment and plans, it must be understood that the primary responsibility for your actions and your own safety rests with you. Please report any unsafe conditions or acts to the TA or the instructor immediately.

Keys to your safety are:

- developing an awareness of possible hazards and safety procedures,
- reducing hazards by eliminating their causes or by modifying procedures
- using common sense to avoid hazards
- using appropriate personal protective equipment (PPE)
- planning and carrying out the experiments carefully
- strictly following the UO Lab safety rules, and
- establishing emergency procedures to deal effectively with accidents.

Hazards are of two types, namely chemical and physical. Accidents in the UO lab, as in the chemical industry, could occur owing to the use of:

- chemicals
- combustible materials
- glassware
- mechanical equipment involving moving parts
- electrical equipment
- high pressure (e.g., gas cylinders)
- vacuum, and
- high temperature (e.g., steam).

The following pages briefly describe the hazards associated with the above and the safety procedures to be followed to avoid accidents. More details may be found in the references listed at the end of this chapter, in particular *Prudent Practices in the Laboratory. Handling and Disposal of Chemicals*, National Academy Press, Washington, DC (1995), *Guidelines for Incorporating Safety and Health into Engineering Curricula* (1994), and *Compliance Guide for OSHA's laboratory Standards*, Health Protection Office, The University of Iowa, Iowa City, IA (1991). Laboratory performance will be graded in part on your strict observance of the following procedures and rules.

EMERGENCY PROCEDURES

In the event of a:

- fire
- chemical hazard
- explosion
- or a life threatening situation,

you should:

- call 911
- activate alarm system
- warn people to evacuate
- leave the building,

and wait for responding personnel from the University of Iowa Department of Public Safety (campus security). For all emergency situations where immediate assistance (police, fire, or ambulance) is required, call 911. You should state your location, the nature of the emergency, and the assistance you are requesting. In the event of a serious building problem which requires immediate attention, you should contact the instructor. In the event of an accident, render assistance and first-aid to the person(s) involved, including use of safety shower, eye wash, etc. Extinguish any small fires by using portable extinguisher. Fire extinguishers, fire alarms, eyewash fountains and emergency showers are all available in the laboratory area.

In the case of a medical emergency, the University of Iowa Hospitals Emergency Room should be contacted at 356-2233. If a chemical is involved, inform the emergency personnel about the identity of the chemical. Do not move the person, unless he or she is in danger of further harm.

To report a theft or other crime, contact University Department of Public Safety at 335-5022. Finally, you should report all problems, accidents, and emergency situations to the course instructor or the department chairman as soon as possible.

CHEMICAL SPILL RESPONSE

At the University of Iowa, individuals are responsible for their own spills. Each hazardous material user must be equipped to handle a spill. To prepare for a possible spill:

- Obtain from department office Material Safety Data Sheets (MSDS) for the hazardous material
- Obtain spill response supplies
- Practice for effective spill response

In case of a minor spill (that does not spread readily or endanger people):

- Notify the TA and Instructor
- Keep the area clear
- Call the Health Protection Office (335-8501) for advice, if needed.
- Plan and execute the cleanup

The primary source of information for spill control is the MSDS and must be consulted. Most spills, fortunately, are water and should be squeegeed. Other small spills (<1/2 cup) of non-toxic liquids may be soaked up with paper towels, which must be disposed-off in a solid-waste container and not a trash can. For other small spills for which there is no fire or toxic hazard, you may clean up the spill, under the supervision of the TA, using adsorbents such as vermiculite, Oil-Dri, Zorb-All, or sodium bicarbonate ($NaHCO_3$, or common baking soda). Make sure that you have the requisite personal protective equipment (next section) such as gloves, apron, safety glasses, etc. After cleanup, the area should be thoroughly washed with soap and water. If the liquid spilled is flammable, shut down all motors and other sources of sparks and heat sources in the lab. Have the lab evacuated before proceeding with the cleanup.

In case of a major spill, that spreads readily or may endanger people, and thus requires specially-trained and equipped persons:

- Call 911
- Activate alarm system
- Warn people to evacuate
- Wait for responders

PERSONAL PROTECTIVE EQUIPMENT (PPE)

The section 20.320 of the *University Operations Manual* describes the university policy on personal protective equipment (PPE). PPE includes clothing and other personal equipment worn by the individual to create a barrier between the hazard and the individual. Use of the following PPE by students, TAs, as well as instructor is required in the UO Lab:

- Wear safety glasses with permanently attached side shields or safety goggles, that comply with ANSI Z87.1-1989, at all times while in the UO lab, in order to protect your eyes and face from fine dust, flying objects, chemical mists, fumes, and sprays. Eyeglasses with plastic or safety glass lenses are an unsuitable substitute for goggles. Contact lenses are not allowed in the UO lab since they can increase the damage in the case of a chemical splash and also interfere with eye-flushing. If you must wear contact lenses for medical reasons, then safety glasses with side shields or safety goggles must be worn over them.
- Wear laboratory coats within the laboratory at all times. Lab coats protect against some chemicals, microorganisms, grease, dirt, etc. Cotton coats, rather than polyester ones, are better since they burn less readily. Wear long pants and other clothing so that large areas of skin are not exposed.
- Wear closed toe, non-porous, shoes to protect the top of the foot and toes. Cloth sneakers or sandals provide little protection against falling glassware, chemical spills, and mechanical impact.
- Wear rubber gloves when handling acids and bases. Use oil-resistant gloves when handling chlorinated solvents; rinse gloves thoroughly before removing them. Use insulated gloves when working with steam/condensate lines.
- Consult MSDS to determine any additional PPE required for handling a particular chemical.

GENERAL UO LAB SAFETY RULES

- Know the location and operation of the following safety equipment (Figure II-1):
    1. fire extinguishers and class (A, B, C)
    2. safety shower
    3. eye wash fountain
    4. fire blanket
    5. first-aid kit and its contents
    6. telephone and emergency phone numbers
- DON'TS:
    - ⇒ No running or horseplay.
    - ⇒ No smoking in the laboratory.
    - ⇒ No eating or drinking in the laboratory.
    - ⇒ No radios, etc.
    - ⇒ No loud or disruptive activity.
    - ⇒ No neckties or dangling clothes or jewelry or long open hair are allowed as they can become entangled in moving machinery.
    - ⇒ No sandals, open-toed shoes, or high-heeled shoes are permitted.
    - ⇒ No sniffing, inhaling, or ingesting any chemicals used in experiments.
    - ⇒ No tools, supplies, or any other items may be tossed from one person to another.
    - ⇒ <u>Never</u> pipette or siphon any material (even water) by mouth.
    - ⇒ <u>Never</u> work alone in the laboratory.
    - ⇒ <u>Never</u> use rubber gloves to touch steam valves or other hot surfaces, since rubber can melt and cause 2nd degree burns
    - ⇒ <u>Never</u> leave operating equipment unattended. The Group Leader is responsible for scheduling any rest room/coffee breaks, etc., such that at least two members of the group are always present while an experiment is being conducted.
    - ⇒ Do not to be in the laboratory area outside of the scheduled working hours (9:30 to 5) without written permission of the instructor.
- Wear the required PPE in the lab at all times.
- Know the emergency shutdown procedure before starting any experiment.

- No equipment is to be operated until the "Permission to Start Experimentation" (form in Appendix B) has been obtained from the TA or the instructor after a safety inspection.
- Keep all UO lab exits and aisles clear and unblocked.
- The UO Lab floor must always be kept dry, clean, and uncluttered. Any spills must be cleaned up immediately.
- Clean up any spills with paper towels or adsorbent clay. Ask the T A for assistance. For a major spill, call 911 or the Health Protection Office (335-8501).
- Any accident or hazardous situation must be reported to the instructor immediately.
- Wash hands before leaving the lab.
- Discourage casual visitors to the lab.
- Students should consult the instructor or TAs whenever there is some question regarding the safe use of equipment, instruments, or chemicals.
- STUDENTS FOUND VIOLATING ANY OF THESE SAFETY RULES WILL RECEIVE AN F IN THE LABORATORY ON WHICH THEY ARE WORKING. A SERIOUS VIOLATION MAY RESULT IN DISMISSAL FROM THE COURSE.

CLEAN-UP

1. <u>After each laboratory period</u>:
    - Clean all glassware thoroughly at the end of each laboratory period.
    - Use a detergent, rinse completely with tap water and then rinse with distilled water. Return the glassware to its proper location.
    - Rinse out all buckets, carboys, and containers with tap water.
    - Mop up any water/condensate spills.
    - All experimental equipment should be placed at its proper location.
    - All trash should be disposed of in waste cans.
    - Any chemical waste must be disposed off properly as described later.
    - Broken glass should be placed in labeled "Sharps" container.
    - Every group will leave their assigned work area clear, clean, and dry.
    - Make sure all water and steam valves are closed.
    - Make sure all gas cylinders and regulators are closed unless they must remain open to prevent equipment damage.
    - The sink area should be clear of all equipment except cleaning supplies.
    - Equipment and instruments should be turned off unless specifically instructed otherwise by the instructor or TA. For example, He flow through the GC is never turned off to avoid burning the elements in the TCD. For long periods of no use, the He flow is turned off but only after the detector current has first been turned off.
2. There may be a portion of time scheduled between each experiment period for general laboratory clean-up. No group will be allowed to begin their next experiment until they have met their clean-up responsibilities. This is not meant to circumvent daily clean-up procedures as outlined in (1) above.

WORKING WITH CHEMICALS

What is a Hazardous Chemical?

- According to OSHA, a hazardous chemical is defined as one that poses a physical or health hazard in at least one scientific study. Therefore, it is safer to treat practically all chemicals as hazardous.
- Hazardous Waste (those with General Characteristics):

  Liquids with flashpoint < 60 ºC, e.g., toluene, ethanol

  Ignitable solids, e.g., picric acid

  Oxidizers, e.g., $KMnO_4$, $NaClO_3$, $NaNO_3$

  Corrosive, e.g., solutions with pH ≤ 2, or pH ≥ 12.5

  Reactive, e.g., those that react with air or water, produce toxic gases, explosives, peroxides

  Toxic, i.e., those with LD < 500mg/Kg

- EPA Listed Hazardous Wastes:

  P type (Acute toxics)

  U type (Toxics, i.e., most other chemicals)

  F type (Waste from non-specific sources, e.g., chlorinated solvents used in degreasing, spent solutions from electroplating)

  K type (Waste from specific sources, e.g., still bottoms from benzyl chloride still)

Examples: Chemical reagents no longer in use

Waste solvents

Chemicals and contaminated materials from spills

Liquid media containing toxic/carcinogenic/ biohazardous material

Incompatible Chemicals

- Incompatible chemicals are those that can react with each other

  ⇒ violently

⇒ with evolution of substantial heat

⇒ to produce flammable products

⇒ to produce toxic products

Safe laboratory practice requires that incompatible chemicals be stored, transported, and disposed in a manner that will prevent their coming together by accident. The following table provides the general categories of incompatible chemicals.

General Classes of Incompatible Chemicals (CRC Handbook, 1992)

A	B
Acids	Bases, Reactive metals
Oxiding Agents	Reducing Agents
Chlorates	Ammonia, anhydrous and aqueous
Chromates	Carbon
Chromium trioxide	Metals
Dichromates	Metal hydrides
Halogens	Nitrites
Halogenating agents	Organic compounds
Hydrogen peroxide	Phosphorus
Nitric acid	Silicon
Nitrates	Sulfur
Perchlorates	
Peroxides	
Permanganates	
Persulfates	

Peroxide Forming Chemicals

Many chemicals are prone to the formation of peroxides over a period of time when allowed to come in contact with air and are an explosion hazard. Table below provides structure of chemicals that are prone to peroxide formation (CRC Handbook, 1992). The next table lists common peroxide forming chemicals. Those in list A should be discarded 3 months after opening, while those in Lists B and C should be tested or discarded after 6 months.

TABLE 7
Types of Chemicals That Are Prone to Form Peroxides

A. Organic structures (in approximate order of decreasing hazard)

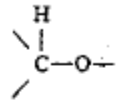
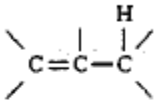
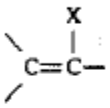
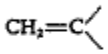
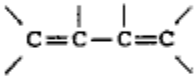
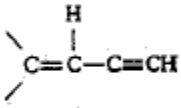
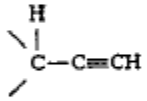
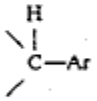
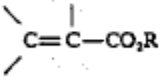
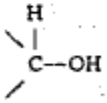
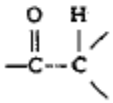
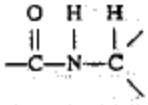
1.		Ethers and acetals with a hydrogen atoms
2		Olefins with allylic hydrogen atoms
3		Chloroolefins and fluoroolefins
4		Vinyl halides. esters, and ethers
5		Dienes
6		Vinylacetylenes with α hydrogen atoms
7		Alkylacetylenes with α hydrogen atoms
8		Alkylarenes that contain tertiary hydrogen atoms
9.		Alkanes and cycloalkanes that contain tertiary hydrogen atoms
10		Acrylates and methacrylates
11		Secondary alcohols
12		Ketones that contain a hydrogen atoms
13		Aldehydes
14		Ureas, amides, and lactams that have a hydrogen atom on a carbon atom attached to nitrogen

TABLE 7
Types of Chemicals That Are Prone to Form Peroxides (continued)

B. Inorganic substances

1 Alkali metals, especially potassium, rubidium, and cesium (see Chapter 6, Section III D)
2 Metal amides (see Chapter 6, Section III C.7)
3 Organometallic compounds with a metal atom bonded to carbon (see Chapter 6, Section IV)
4 Metal alkoxides

TABLE 8
Common Peroxide-Forming Chemicals

LIST A

Severe Peroxide Hazard on Storage with Exposure to Air

Discard within 3 months

- Diisopropyl ether (isopropyl ether)
- Divinylacetylene (DVA)[a]
- Potassium metal
- Potassium amide
- Sodium amide (sodamide)
- Vinylidene chloride (1,1–dichloroethylene)[a]

LIST B

Peroxide Hazard on Concentration; Do Not Distill or Evaporate Without First Testing for the Presence of Peroxides

Discard or test for peroxides after 6 months

- Acetaldehyde diethyl acetal (acetal)
- Cumene (isopropylbenzene)
- Cyclohexene
- Cyclopentene
- Decalin (decahydronaphthalene)
- Diacetylene
- Dicyclopentadiene
- Diethyl ether (ether)
- Diethylene glycol dimethyl ether (diglyme)
- Dioxane
- Ethylene glycol dimethyl ether (glyme)
- Ethylene glycol ether acetates
- Ethylene glycol monoethers (cellosolves)
- Furan
- Methylacetylene
- Methylcyclopentane
- Methyl isobutyl ketone
- Tetrahydrofuran (THF)
- Tetralin (tetrahydronaphthalene)
- Vinyl ethers[a]

LIST C

Hazard of Rapid Polymerization Initiated by Internally Formed Peroxides[a]

a. Normal Liquids, Discard or test for peroxides after 6 months[b]

- Chloroprene (2–chloro–1,3–butadiene)[c]
- Styrene
- Vinyl acetate
- Vinylpyridine

b. Normal Gases, Discard after 12 months[c]

- Butadiene[c]
- Tetrafluoroethylene (TFE)[c]
- Vinylacetylene (MVA)[c]
- Vinyl chloride

[a] Polymerizable monomers should be stored with a polymerization inhibitor from which the monomer can be separated by distillation just before use.

[b] Although common acrylic monomers such as acrylonitrile, acrylic acid, ethyl acrylate, and methyl methacrylate can form peroxides, they have not been reported to develop hazardous levels in normal use and storage.

[c] The hazard from peroxides in these compounds is substantially greater when they are stored in the liquid phase, and if so stored without an inhibitor they should be considered as in LIST A.

The containers of all peroxidizable chemicals should be labeled with one of the following:

For List A:

```
Peroxidizable Compound
      Recd.        Opened
Date  ______       ______
Discard 3 months after opening.
```

For List B:

```
Peroxidizable Compound
      Recd.        Opened
Date  ______       ______
Discard or test for peroxides
   6 months after opening.
```

Safety Procedures for Hazardous Chemicals

- Learn the toxic properties of each chemical by obtaining its Material Safety Data Sheet (MSDS) containing information regarding the potential chemical, physiological, mechanical, and other hazards associated with the chemical. A sample MSDS is given in Appendix B. A notebook containing a large number of MSDS is located in the UO Lab. If you cannot find the necessary MSDS, then obtain it from supplier.
- Every single glassware or container containing a chemical must be labeled. Use a grease pencil or masking tape label to indicate the chemical name, your name, and the date.
- Wear rubber gloves when handling acids and bases. Use oil-resistant gloves when handling chlorinated solvents; rinse gloves thoroughly before removing them.
- Utilize fume hood for handling flammable or toxic chemicals including carcinogens, reproductive toxins, and chemicals of unknown toxicity.
- Store flammable chemicals in an approved flammable storage cabinet.
- Do not store incompatible chemicals close to one another in the laboratory (e.g., acids and bases). Organic solvents should be stored in a different location than acids and bases. Do not store in alphabetical order.

- Discard peroxide forming chemicals 3 to 6 months after opening container.
- All chemicals must be transported in a safety carrier (bucket or other suitable container).
- Do not dump organic solvents down the drain. Ask the TA for assistance.
- Dilute acids and bases may be neutralized to pH 7 and flushed down the drain using plenty of cold water.
- Use a class B fire extinguisher for chemical fires.
- Obtain spill response supplies mentioned earlier.
- Practice for effective spill response.
- Clean up any spills with paper towels or adsorbent clay--ask the TA for assistance. For a major spill, call 911 or the Health Protection Office (335-8501).
- Acids and bases, if dilute, may be flushed down the drain using plenty of cold water. If pH < 2.0 or > 12.5, then they are treated as hazardous waste. They may be neutralized to pH 7 and flushed down the drain using plenty of cold water.

LAB SAFETY EQUIPMENT FOR WORKING WITH CHEMICALS

Fume Hoods

The purpose of a fume hood is to protect you from air borne chemical fumes and to provide a local exhaust in the lab. A secondary purpose is protection from small fires or explosions. The fume hood may be tested by "face velocity" and "smoke testing" methods. It is considered to be adequate if the face velocity is 100 fpm with the sash half open.

- All volatile chemicals should be handled within the fume hood.
- Lower sash while working so that you may protect yourself from accidental splashes or small explosions.
- Store hazardous and volatile toxic materials in vented cabinets below fume hoods.
- Do not store chemicals in fume hoods except for those being used currently.

Flammable Liquid Storage Cabinets

- All volatile chemicals should be stored in approved flammable liquid storage cabinets.
- All materials in the flammable liquid storage cabinets should be labeled with contents, owner, date of acquisition, and potential hazards.
- Store only compatible chemicals in a particular flammable-liquid storage cabinet.

Laboratory Refrigerators

- All materials in the chemical storage refrigerators should be labeled with contents, owner, date of acquisition, and potential hazards.
- Flammable liquids should be stored only in explosion-proof chemical storage refrigerators, which are designed not to spark inside the refrigerator.
- The containers should be sealed to minimize escape of vapors.
- No food should be stored in chemical storage refrigerators.
- The refrigerator should be locked with keys provided only to authorized personnel.

Safety Shower

Use in case of a chemical spill on a person or fire.

- Stand under the shower and pull chain.
- The victim will be deluged in water.
- Remove clothing in case of a major spill.

Eye Wash Fountain

Use in case of a chemical splashed into eyes.

- Depress lever on the fountain. The water pressure should remove the cap.
- Wash eyes for 15-20 minutes. A second person may assist in keeping the eyelids open.
- Remove any contact lenses.

First-Aid Kit

The first-aid kit should contain the following:

- 16 pkg. of 2 gauze compresses
- 6 2 in. x 10 yd. gauze bandage rolls
- 4 3 in. x 10 yd. gauze bandage rolls
- 3 1 in. x 10 yd. plastic adhesive bandage
- 1 box of 100 3/4 in. x 3 in. adhesive bandages
- 1 triangular bandage-sling
- 1 scissors
- 1 tweezers

DISPOSAL OF CHEMICAL WASTE

The Resource Recovery and Conservation Act of 1977, the "Superfund" law, and the Toxic Substances Control Act, and their various amendments and extensions control the dosposal of hazardous waste. At the UI, the Health Protection Office (HPO) picks up the hazardous waste from the laboratories and is responsible for its final disposal. Their procedures must be followed and suitable containers must be used for the disposal of chemical waste. In general, all dilute acids must be placed in high-density polyethylene (HDPE) lined containers for disposal. Strong acids and oxidizing agents should be placed in 1 gallon acid bottles with safety coating. Mixtures of organic solvents in water should be placed in HDPE lined containers. Nonaqueous organic solvents must be placed in Underwriter's Laboratory (UL) approved waste cans. Sold waste can be put in capped 5-gallons pails. The various categories of waste mentioned above should never be mixed.

Procedure

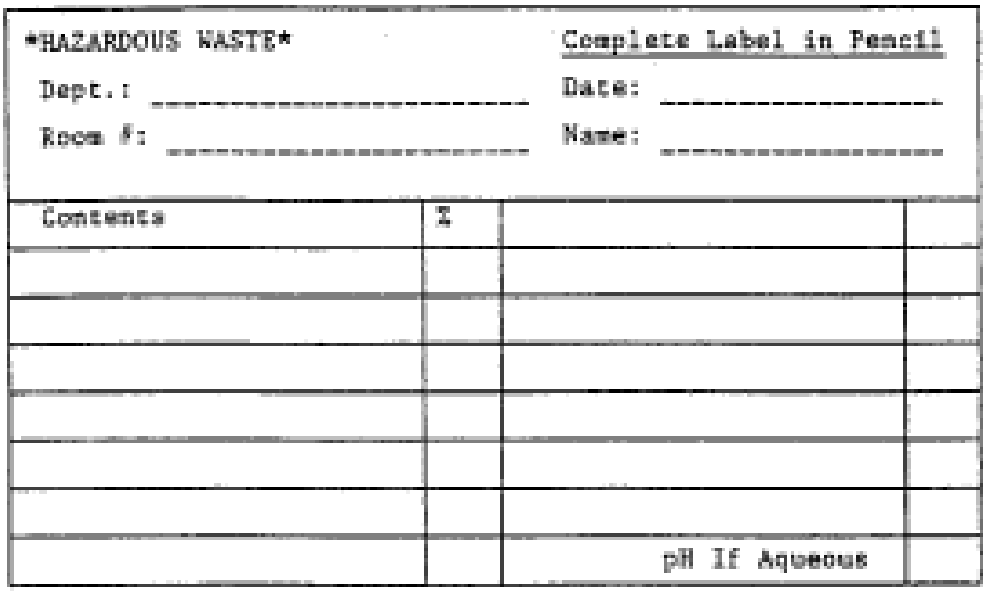
- Use a compatible, capped container
- Label containers only with HPO provided labels in pencil
- Fill out Hazardous Waste Pickup Request Form (see Appendix)
- Call HPO (5-8501) and request pickup at point of generation

Label #1 (for materials in original containers):

HAZARDOUS WASTE HAZARDOUS WASTE
Dept: _____ HPO Code
Rm/Bldg: _____ _____
Name: _____ / /
Date: _____ / /
/_____/

– Complete Label in Pencil –

Label #2 (for wastes not in original containers, or commingled):



Hazardous Waste Packaging Guidelines

- For Waste Flammable Solvents:

1. Use container and closure compatible with waste.
2. Commingle organic solvents only within the six groups listed below:
    a. Halogenated (contains F, Cl, Br, or I)
    b. Hydrocarbons (Contain only C, H, and O)
    c. Contains N
    d. Contains S
    e. Reactive
    f. Oils
3. Complete hazardous waste label #2 listing each major solvent and attach to container.

- For Chemicals in Original Container:
  1. If the original label is legible and tightly affixed, complete hazardous waste label #1 and attach to container (but not over original label).
  2. If original label is illegible and/or loose, complete hazardous waste label #2 and attach to container.

- For Chemicals not in Original Container:
  1. If container was previously used to package chemicals, efface the original label by marking XX through it.
  2. Complete hazardous waste label #2 and attach to container.

- Non-Radioactive Liquid Media Containing Toxic/Carcinogenic Materials:
  1. Collect in a suitable container.
  2. Add a sufficient amount of an appropriate disinfectant to prevent the growth of microorganisms.
  3. Complete hazardous waste label #2 and attach to container.

- Non-Radioactive Solid Toxic Waste Resulting from Clean-up of Chemical Spills, etc.:
  1. Double bagged and boxed; use plastic lined cardboard box or other suitable container.
  2. After filling, tie plastic bag.
  3. Seal box with tape.
  4. Complete hazardous waste label #2 and attach to container. Identify chemical and approximate quantity of any other contents such as gloves, plastic, paper, etc.

- Non-Radioactive Chemical Waste Containing Biohazardous Material
  1. Collect in a suitable container.
  2. Add a sufficient amount of an appropriate disinfectant to decontaminate the biohazardous material.
  3. Complete hazardous waste label #2 and attach to container.

FIRE HAZARD

Fires and explosions are a very real hazard of flammable chemicals (e.g., organic solvents). Explosion of 1 gallon of toluene can destroy the UO Lab and its occupants. Fire prevention and preparedness is a very important part of lab safety. Most flammable liquids have relatively heavy vapors that tend to stay down. Sometimes these heavy vapors flow down and away from the container and can ignite at a distance and flash back to the liquid. The relative ease with which a flammable solvent can be ignited is indicated by the following properties, determined by standardized tests:

- Flammable Liquid - Any liquid that emits flammable vapors at temperatures below 100 ºF.
- Combustible Liquid - Any liquid that emits flammable vapors at temperatures of 100 ºF or higher.
- Flammable Limits - The lower flammable limit is the minimum volume % of a vapor in air that can ignite if an ignition source is present. The upper flammable limit is the maximum volume % of a vapor in air above which the mixture is too rich to burn.
- Flash Point - The lowest temperature at which the vapor pressure of a liquid is enough to form an ignitable vapor-air mixture near the surface of the liquid.
- Ignition Temperature - The minimum temperature for spontaneous combustion without an ignition source

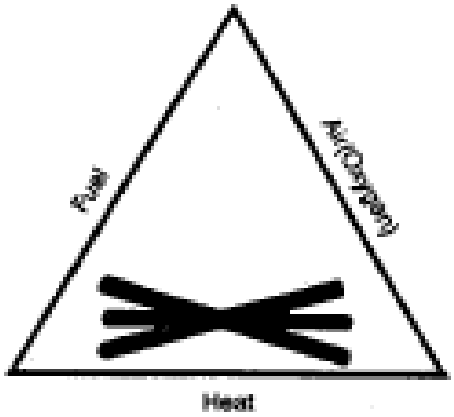
The various classes of flammable and combustible liquids are defined in the table below.

Classification	Flash Point (ºF)	Boiling Point (ºF)
IA	< 73º	< 100º
IB	< 73º	≥ 100º
IC	73º to 100º	≥ 100º
II	100º to 200º	≥ 100º
IIIA	140º to 100º	≥ 100º
IIIB	> 200ºF	≥ 100º

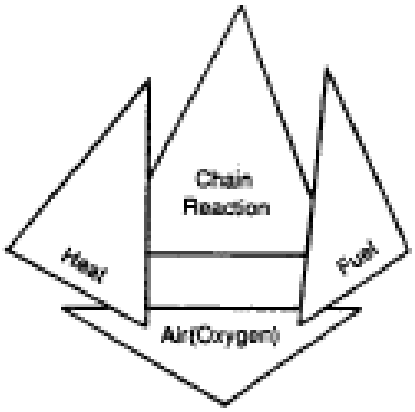
Types of fires:

Fires are of two types:

1. Surface fire: Occurs on exposed surfaces of fuels and does not involve formation of free radicals. Represented by *Fire Triangle*:



2. Flame fire: represented by *Fire Tetrahedron*. Combustion proceeds through rapid formation and combustion of free radicals.



No fire can start or maintain itself unless all elements of the Fire Triangle or Fire Tetrahedron are present, i.e., fuel, oxidant, heat or spark, and free radicals. To avoid fires, control ignition sources, i.e., sparks, flames, static electricity, heat, friction, smoking, electric motors, etc.

Fire vs. Explosion:

Difference is in the rate of energy release. Explosions are sudden and violent onset of flame fires in vapors.

Hazards of Fire

Fire hazards are associated with the following categories: 1) flames, 2) heat, 3) fire gases, and 4) smoke. Fires in enclosed areas are particularly hazardous, since in addition to the above hazards, there is also a depletion of oxygen.

- Flames can produce burns either on contact or at a distance by convection and radiation.
- Heat exposure leads to exhaustion, respiratory problems, and death. Human beings can tolerate air temperatures up to 300 ºF, but only for a short period.
- Fire gases resulting from combustion such as CO, CO_2, acrolein, hydrogen cyanide, hydrogen sulfide, and nitrogen oxides, are extremely dangerous, and cause more deaths than flames or heat.
- Smoke consists of aerosol particles, i.e., liquid droplets, tarry particles, and carbon, resulting from the combustion of materials such as wood, plastic, fabric, coal, oil, etc., and can impair vision. Further, smoke particles can absorb fire gases and become more toxic

Classes of fires:

Class A: (Green triangle) Fires involving combustible solids, e.g., wood, coal, plastics, paper, cloth. Best extinguished by cooling with water or blanketing with certain dry chemicals.

Class B: (Red square) Fires involving flammable or combustible liquids, e.g., ethanol. toluene, and diesel. Best extinguished by excluding air or by chemicals that quench the combustion chain reaction.

Class C: (Blue circle) Fires involving combustible materials in electrical equipment. Best extinguished by nonconducting agents such as CO_2, Halons, and certain dry chemicals.

Class D: (Green star) Fires involving combustible metals, e.g., Mg, Ti, Zr, Na, and K. Best extinguished by special agents.

Fire extinguishers act by:

- Cooling: e.g., by water
- Diluting the oxygen supply, e.g., CO_2 or Halon types
- Forming a barrier between combustible materials and oxidants, e.g., dry powder types
- Breaking free radical chain reaction in flames, e.g., Halon types.

Portable Fire Extinguishers:

Fire extinguishers are labeled with special color-coded symbols to indicate the classes of fires they are suitable for (see table below). Thus

Class A - green triangle

Class B - red square

Class C - blue circle

Class D - green star

Multipurpose fire extinguishers are labeled for each class of fire on which they can be used, e.g., A,B,C.

Fire Class	Extinguishing Agent
A	Water
A, B	Foam
A, B, C	Ammonium phosphate
B, C	Carbon dioxide
B, C	Potassium bicarbonate
B, C	Potassium chloride
B, C	Potassium bicarbonate/urea
B, C	Halon 1211 (bromochlorodifluoromethane)
B, C	Halon 1301 (bromotrifluoromethane)

Use of Fire Equipment

- Small fires: Use dry chemicals or CO_2
- Large fires: Use water spray, or foam
- Water works primarily as a coolant and is used commonly as a stream, spray, or foam. Not used for low flash point liquids, e.g., gasoline, and electrical fires.
- CO_2 primarily works as an air diluent and is used for flammable liquids and electrical fires.
- Dry chemicals ($Na/KHCO_3$, KCl, urea, mono ammonium phosphate) work by coating and smothering the fire and are used mainly for fires B and C.
- Halons (easily liquefied vapors) work by interfering with combustion reactions and are very effective for fires B and C. However, they decompose in fire to carbonyl chloride (phosgene) and other toxic gases.
- Fire blankets may be used when clothing is on fire, but safety shower is highly preferable.

Operation of Fire Extinguisher

- Remove from wall
- Pull pin
- Point nozzle at base of flame
- Squeeze handle
- Slowly advance toward flame

WORKING WITH COMPRESSED GASES

A compressed gas is defined as a material in a container with absolute pressure greater than 40 psi at 21 ºC (70 ºF).

- Typical gas cylinders are under very high pressure and can pose serious physical and chemical hazards. Know the contents of the cylinders and consult the MSDS for its properties and hazards and for any special PPE beyond safety goggles.
- Purchase the smallest cylinder compatible with need. Use only in well-ventilated area.
- All gas cylinders should be stored upright and secured safely to a bench or wall using cylinder clamp or chain.
- Gas lines leading from a cylinder should be labeled with the identity of the gas.
- Signs should be posted next to flammable gas cylinders, e.g., "HYDROGEN--FLAMMABLE GAS--NO SMOKING--NO OPEN FLAMES."
- Flammable gases should be kept far away from all sources of heat or sparks. Cylinder should never be subjected to temperatures > 125 ºF.
- Only proper Compressed Gas Association (CGA) regulators recommended for the gas or liquid contained in the cylinder should be used. Cylinder regulator adapters should never be used. The pressure regulator should be equipped with a spring-loaded pressure-relief valve.
- Teflon tape must never be used on any CGA cylinder valve fitting. CGA fittings involve metal-to-metal threaded seals that do not require Teflon tape or other sealing material.
- Do not use oiled/greased regulators or pressure gages for air, oxygen, or other oxidants.
- The main cylinder valve should remain closed except when the gas is being used.
- Leak test all connections with a soap solution.
- Make sure that the apparatus using high pressure gas has a pressure relief valve.
- Use of plastic tubing, e.g., Tygon, in pressure applications should be avoided since it can become brittle with use and break, in which case it can also whip around.
- The exhaust should always be vented in a hood.

- When being stored or moved the regulator should be removed, the gas cylinder valve closed, and the protective cap replaced.
- If a gas cylinder is empty, please inform the TA, so that it may be returned to the supplier.
- Ask the TA for assistance in changing the cylinder.
- Only move a cylinder on a cylinder cart after chaining the cylinder to the cart. Never drag, roll, or slide a cylinder.

WORKING WITH STEAM/CONDENSATE LINES

- Use insulated gloves for operating steam valves.
- Open steam valves slowly.
- Never use rubber gloves to touch steam valves or other hot surfaces, since rubber can melt and cause 2nd degree burns.
- During initial startup, bypass steam traps until live steam appears.
- Stay clear of condensate discharge lines during startup.
- Keep hands and clothes away from bare steam lines and traps.

WORKING WITH GLASSWARE

- Use only clean and dry glassware.
- After use all glassware should be cleaned with detergent and brush. Dry it with air.
- If special cleaning solution is required, use eye protection.
- Label glassware and other containers with their contents using a grease pencil or masking tape label. The label should indicate the chemical name, your name, and the date.
- Seal test tube with a stopper, not your thumb.
- Use hand protection such as towel or glove when inserting glass tubing into rubber stoppers, etc.

- Thermometers and more than one piece of glassware must be transported in a bucket or other suitable container
- Never use chipped or cracked glassware.
- Ground glass joints or stopcocks should have Teflon sleeves or should be greased.
- Clamp glass equipment making sure it is not stressed.
- Place glass apparatus where it is unlikely to be knocked over.
- Use only glassware designed for vacuum applications.
- Dispose off broken glassware in the "Sharps" container.
- Always use eye protection when handling glassware.

WORKING WITH MECHANICAL EQUIPMENT

- All moving parts such as belts, chains, shafts, and couplings should have guards.
- Keep clothing, hands, and hair away from moving parts such as pumps, agitators, etc. Neckties or dangling clothes or jewelry can become entangled in moving machinery.
- Do not run the pumps dry. Prime the pumps.
- Make sure the agitator is off before adding materials.
- Turn off motor and wait till the agitator is completely stopped before touching it.
- Check tubing, connections, and hoses to make sure that they are tight and leak-proof. Use soapy water to check for leaks in pressurized gaseous systems.
- In vacuum apparatuses, locate relief valves and understand their function.
- When using a manometer, open and close the low-pressure, high-pressure, and the by-pass valves slowly and in a sequence that would ensure that Hg stays in the manometer.
- In vacuum apparatuses, locate relief valves and understand their function. Use only glassware designed for vacuum applications.

WORKING WITH ELECTRICAL EQUIPMENT

- Use “left hand” rule, i.e., use left hand to flip power switches, facing away from box, in case of explosion.
- Make sure that the power is off before making electrical connections or repairs. Qualified individuals should do repairs.
- If possible, work with only one hand while keeping the other at your side or in your pocket, away from conducting materials. This reduces the likelihood of current passing through the chest cavity.
- Avoid being grounded by staying away from walls, water, metal equipment, and pipes.
- Before reconnecting electrical equipment to power source, check with a multimeter to ensure that it is properly grounded.
- Do not reenergize a circuit breaker until it is made sure that the problem that activated it has been corrected.
- Avoid using extension cords, particularly in traffic or wet areas. Extension cords are not allowed in place of permanent wiring. Make sure that people won’t trip over any extension cords. Certainly, do not use frayed extension cords or those with broken plugs.
- Use three-pronged plugs that provide an independent ground connection to the chassis of the apparatus (Figure II-2).
- Do not spray water on electrical equipment.
- Use class C fire extinguisher for fires involving energized electrical equipment.
- If a person is electrocuted, first disconnect the power source before removing the person and giving first aid.

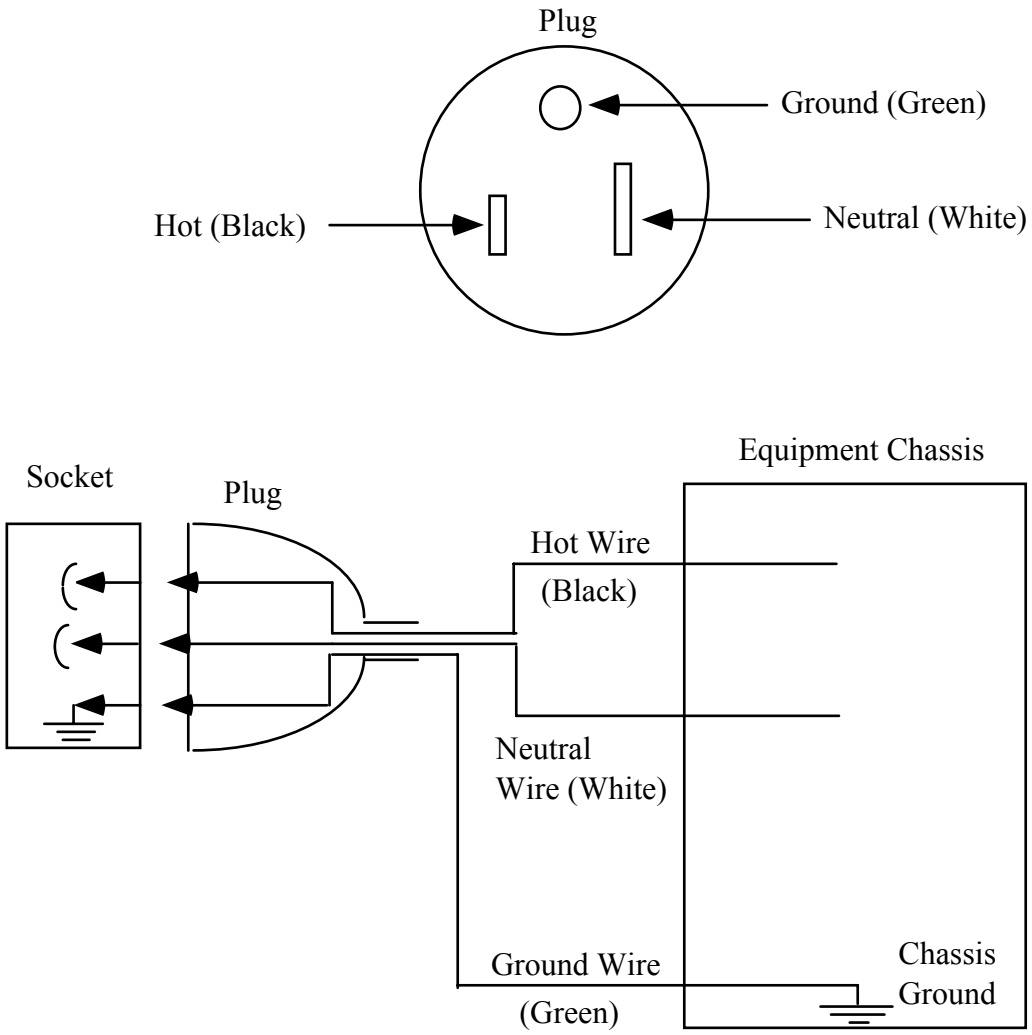


Figure II-2. Standard three-wire grounded wiring connection for 110-V electric power (adapted from *Prudent Practices in the Laboratory. Handling and Disposal of Chemicals*, National Academy Press, Washington, DC, 1995).

EXPERIMENT SAFETY CHECKLIST

Hazard Recognition

- What materials, equipment, conditions, procedures are used?
- What are hazardous properties of materials used?
- Can the hazardous materials be released into the lab?
- Is hazardous waste generated? How will it be disposed?
- What are the mechanical hazards (e.g., unguarded gears, sprockets, pulleys)?
- What are the electrical hazards (e.g., is machine properly grounded)?
- Hazards due to high P, T, or vacuum?
- Other potential hazards?
- What if ...scenarios? For example, what if cooling water stopped? What are the chances? What are the consequences?
- Who may be exposed to the hazards?
- Possible effects of an accident?

Hazard Abatement and Response

- Obtain MSDS
- Are all group members familiar with a safe operating procedure?
- Is it necessary to work in the hood?
- Is adequate space available?
- Is there adequate ventilation?
- Is there adequate light?
- Is any special safety equipment necessary besides that required in the lab?
- Are all group members aware of potential hazards and location of safety equipment in the lab?
- Are emergency shutdown procedures (quite different from normal shutdown) clearly established?
- Are emergency switches/valves within easy reach?

- Can hazard be reduced in any way, e.g., by eliminating any leaks, reducing inventories and use of hazardous materials, adding a relief valve, etc. ?

EXAMPLE OF AN EXPERIMENT

Double-Pipe heat Exchanger

Safety Procedures

- Steam is used. Therefore, high P and T hazard.
- Use insulated glove for operating the steam valve.
- Open steam valve slowly.
- Stay clear of steam traps, especially when steam is first turned on.
- Be sure condensate line hose extends securely into drain.
- Avoid touching the exposed heat exchanger surfaces.
- Control flow rates to heat exchanger with valves on the inlet so as to avoid pressurizing the heat exchanger.
- Be mindful of water, condensate spills. Mop up any spills immediately.

Emergency Procedures

- Shut off the steam valve.
- Close the water valve.
- Evacuate laboratory.

Recommendations

- Relocate steam valve to make it more accessible.

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