I. INTRODUCTION

Safety in the laboratory requires the same kind of continuing attention and effort that is given to research and teaching. The use of new and/or different techniques, chemicals, and equipment requires careful preparation. Reading, instruction, and supervision may be required, possibly in consultation with other people who have special knowledge or experience. Each individual who works in a laboratory has a responsibility to learn the health and safety hazards associated with the materials to be used or produced, and with the equipment to be employed.

It is important for you to know what is expected of you and what your responsibilities are with regard to safety to yourself, your colleagues and our environment. In addition, there are safety practices and safety equipment with which you must be thoroughly familiar if you are to work safely in the laboratory. This manual should be used as a guide to the general types of hazards and a reference source for more specific information pertinent to each individual project.

II. FIVE PRINCIPLES OF SAFETY

Our Safety Program incorporates only a few principles, but each one is essential. These principles are: 1) practice safety, 2) be concerned about the safety of others, 3) understand the hazards associated with your particular experiment, 4) know what to do in an emergency, and 5) report hazards or hazardous conditions.

1) Practice Safety

One problem concerning the practice of safety is that it is a subjective matter. For example, some people consider smoking safe while others do not. In order to have an effective safety program, some common ground rules must be established. This is the main purpose of this Safety Manual. Some of the more basic safety practices that you are expected to follow are:

a) Wear appropriate eye protection whenever working with any potential eye hazards (safety glasses, chemical goggles and face shields are available in the Laboratory Stock Rooms).

b) Use a hood for hazardous, volatile, and noxious chemicals.

c) Label an experiment to show its associated dangers and the persons to contact in case of a problem. There should also be an up-to-date card posted visibly outside each room listing the responsible persons to call in the event of problems in the room.

d) You are further expected to secure all gas cylinders, to label all containers, to observe posted signs, such as no smoking, and so on.

e) While the University provides safety equipment in the hallways of buildings, it is the individual's and their advisor's responsibility to provide safety equipment in the laboratories.

It does not end here, because the list is actually endless. Each situation requires its own safety practices, which you are expected to know or find out before doing an experiment.

2) Be Concerned About The Safety of Others

Your concern for safety must include the people around you. Your experiment must be safely maintained so that everyone in the area is amply protected and warned of inherent dangers. In addition, this principle of looking out for the other person should include the practice of pointing out unsafe procedures to those people committing the unsafe act. This practice could involve something as simple as reminding a friend to wear safety glasses. Another aspect of this second principle involves alerting those around you of an accident. It is your responsibility to alert personnel in the immediate vicinity of a fire or an emergency!

3) Understand the Hazards Associated with Your Particular Experiment

Prevention is the key to safety. Prior to designing any experiment, using a new piece of equipment, or handling chemicals in the laboratory, it is wise to consider the potential hazards and safety precautions involved in the work. Hazards may include toxic substances, electrical circuits, mechanical equipment, and waste chemicals. Safety precautions should include correct materials storage, proper ventilation, proper grounding of equipment, and training sessions when necessary. Whenever possible, information about the unique hazards and precautions necessary for any type of work should be prepared and made available to everyone working in the lab. Material Safety Data Sheets (MSDS) and equipment manuals are important sources of information. Prior to starting any experiments, an MSDS which includes toxicological information and special handling requirements should be obtained and read for each chemical to be used. The Environmental Health and Safety Office (EH&S) maintains a file of thousands of MSDS's and is available to assist in obtaining them (5-6391). EH&S personnel are also available to review the project safety requirements and potential hazards with you. An example of an MSDS for acetone is included in Appendix B.

4) Know What to do in an Emergency

You must be prepared to respond quickly and precisely to an emergency. You must familiarize yourself with the laboratory you are working in, its exits, and its associated safety equipment: eyewash stations, showers, fire extinguishers, and spill kits (Spill kits are available in Room 230). Appendix A of this manual contains a floor plan which pinpoints the location of each of these in MRL. Just a few moments spent learning the locations and use of these pieces of equipment prior to an emergency could save a life.

If the emergency is of an infiltrating nature, such as a fire, gas leak, release of toxic fumes, or radiation leak, the following procedures should be followed:

- **Alert personnel in the immediate vicinity.**
- **Confine the fire or emergency, if possible.**
- **Summon aid**
- **Evacuate the building.**
- **Report pertinent information to responding emergency personnel.**

It is worth commenting on each of these procedures.

Alert personnel in the immediate vicinity - When alerting personnel in the vicinity of a fire or emergency, assign several of them the responsibility of assisting in the remaining procedures. Especially assign someone the task of summoning aid!

Confine the fire or emergency, if possible - Confining fires or other emergencies means taking measures to prevent them from spreading. In case of fire, close doors and windows securely. If the fire is not threatening you, use an appropriate fire extinguisher. Do not waste valuable time trying to confine an emergency when it is beyond your control. Follow evacuation procedures.

Evacuate the building. - Evacuating the building means sounding the fire alarm system and going to the nearest exit without delay. The elevator should never be used during a fire!

Summon aid. - The Fire Department, the Police Department, and Medical Services can be contacted by dialing . When summoning aid, phone from a safe location. You should be

prepared to state precisely the location and nature of the emergency. Do not hang up until you have given all of the pertinent information and you are instructed to do so by the dispatcher. University medical response time is around 3 minutes to anywhere on campus.

Report pertinent information to responding emergency personnel - Meet, or designate someone to meet, responding emergency personnel at a specific location and report pertinent information such as: personnel trapped, specific location of incident, hazardous materials or equipment involved.

If the emergency does not necessitate a confinement or evacuation procedure, such as an individual being injured, you must still be prepared to alert nearby personnel and summon aid. You may also have to administer some emergency treatment yourself. This emergency treatment could involve the use of safety equipment mentioned previously.

5) Report Hazards or Hazardous Conditions

You must report any incidents without delay.

. The building safety officer and your supervisor/advisor should also be notified.

The remainder of this Safety Manual presents examples of hazards that you are likely to encounter in the laboratory and what you should know about them to minimize their danger to you and to others.

III. EMERGENCIES AND FIRST AID

In a medical emergency, summon professional medical attention immediately by dialing 911 from any university phone. Be prepared to describe accurately the nature of the accident. Provide first aid within the scope of your training while waiting for professional help to arrive. It is important you do not attempt any medical treatments you are unfamiliar with. Report all injuries to your supervisor/advisor.

Use of Emergency Equipment - Everyone working in labs must know how to use emergency equipment such as fire extinguishers, spill kits, safety showers, and eye wash apparatus. Special training on the proper use of all types of emergency equipment is available by calling the Environmental Health and Safety office. Know where these items are located in your laboratories.

First Aid

There are certain serious injuries in which time is so important that treatment must be started immediately.

A. Stoppage of Breathing

For stoppage of breathing (e.g. from electrical shock or asphyxiation), the mouth-to-mouth method of resuscitation is far superior to any other known. If victim is found unconscious on the floor and not breathing, rescue breathing must be started at once, seconds count. Do not waste time looking around for help, yell for help while resuscitating victim.

Training in the techniques of mouth-to-mouth resuscitation and Cardio-Pulmonary Resuscitation (CPR) is available

B. Severe Bleeding

Severe bleeding can almost always be controlled by firm and direct pressure on the wound with a pad or cloth. The cleaner the cloth, the more desirable; however, in an emergency, use part of the clothing. In addition:

1. Wrap the injured to avoid shock, and call immediately for medical attention.
2. Raise the bleeding part higher than the rest of the body and continue to apply direct pressure.
3. Keep victim lying down.
4. Never use a tourniquet.

C. Thermal Burns

1. If the burn is minor, apply ice or cold water.
2. In case of a clothing fire:
   a. The victim should drop to the floor and roll, not run to a safety shower. A fire blanket, if nearby, should be used to smother the flames.
   b. After flames are extinguished, deluge the injured under a safety shower, removing any clothing contaminated with chemicals.

c. Keep the water running on the burn for several minutes to remove heat and wash area.
d. Place clean, soaking wet, ice-packed cloths on burned areas, and wrap to avoid shock and exposure.
e. Never use a fire extinguisher on a person with burning clothing.

D. Chemical Burns

1. For chemical burns or splashes, immediately flush with water.
2. Apply a stream of water while removing any clothing that may have been saturated with the chemical.
3. If the splash is in the eye, flush it gently for at least fifteen minutes with clear water. Wash in a direction away from the other eye. Have aid summoned immediately!
4. If the splash is on the body, flood it with plenty of running water for at least 15 minutes. If the exposure is over a small area, have someone drive you to Ritenour Health Center for proper medical attention following the first aid treatment. For large scale exposure have someone call the university ambulance
5. A safety shower, hose, or faucet should be used in an emergency.
6. For chemicals spilled over a large area, quickly remove contaminated clothing while using the safety shower; treat as directed under the section thermal burns. Seconds count, therefore, no time should be wasted simply for modesty.
7. If safety goggles are worn during a chemical exposure to the face, leave them on until the surrounding area is thoroughly rinsed, they may be the only thing keeping the chemical out of your eyes.

E. Traumatic Shock

In cases of traumatic shock, or where the nature of the injury is not clear, keep the victim warm, lying down and quiet. Wait until medical assistance arrives before moving the victim. One should treat all injuries as potential shock situations, as they may turn into one. Some common symptoms of shock are cold and clammy skin, paleness, and deleria.

IV. SAFETY RULES

General Laboratory Practice

Personal Precautions:

1. Working alone is not good laboratory practice. An individual is advised to work only under conditions in which appropriate emergency aid is available when needed. In other words, try to work when others are around to provide help if it is needed. If others are working nearby, let them know where you will be working so that they can occasionally check on you and you can check on them.

2. Eye Protection. In all laboratories where chemicals are used there is the hazard of splashes or dust particles entering the eyes. Pressurized or vacuum vessels may explode or implode sending shrapnel through the lab. While working with electrical wiring there are hazards from molten solder and debris. When testing samples on Instrons or other equipment, pieces can chip and enter the eye. Protective goggles rated for the correct wavelength should also be used around lasers and UV radiation sources. All of these activities, and many others require the use of either safety glasses, chemical goggles or face shields. Most lab operations simply require the use of safety glasses, however, when any chemicals are being used at least chemical goggles should be used or in some cases a face shield is required. The appropriate eye protection is generally specified on the MSDS.

3. Ear Protection. The healthy ear can detect sounds ranging from 15 to 20,000 hertz. Temporary exposure to high noise levels will produce a temporary hearing loss. Long term exposure to high noise levels produces permanent hearing loss. There appears to be no hearing hazard (although possible psychological effects) to noise exposure below 80 dB. Exposure above 130 dB is hazardous and should be avoided. Ear muffs offer the highest noise attenuation, and are preferred for levels above 95 dB. Ear plugs are more comfortable and are preferred in the 80-95 dB range. If you suspect that a hearing hazard exists then notify Environmental Health and Safety to have the sound level measured.

4. Respiratory Protection. Use only respirators provided and/or recommended by EH & S. There are many shapes and sizes of respirators and in order to be effective it must be properly fitted. There are also a variety of cartridges available each having a specific application. The cloth respirators available in the stockrooms provide only minimal dust protection and no

chemical protection. They should never be used with any toxic material. Respirators should only be used following proper fitting and instruction by EH&S personnel. Care should also be taken to avoid inhaling fine particles and whiskers.

5. Clothing. In situations where splashing or spills may occur it is wise to protect your b y with lab coats, goggles and face shields, splash aprons, and gloves may be needed for chemicals that are corrosive or easily absorb through the skin. Shorts and open-toed shoes are not recommended when working in the lab. Do not work in a laboratory wearing loose hair, loose clothing or dangling jewelry. Any questions regarding appropriate protective equipment can be directed to EH&S.

6. Hand Protection. For any laboratory procedure requiring the use of gloves, make sure you are using gloves made of a material suitable for the operation. Gloves are made of a variety of materials and have specific uses, if used improperly they may not provide the necessary protection. The MSDS should specify the glove type but if in doubt call EH&S for assistance.

7. **Consumption of food and beverages in the labs is not permitted. Cooking of food in the laboratory is also not permitted. Never use a microwave oven or other equipment used to process materials for the preparation of food.**

8. Wash hands and arms prior to leaving the laboratory.

Laboratory Practice

A. Hazardous Chemicals

1. All containers must be labeled (including such harmless items as distilled water). The label should contain the proper name of the chemical and, if appropriate, a statement of hazards (with the most severe first), precautions, date of purchase or synthesis, and the name of the user. If cleaning Pt crucibles in HF, label the container with a warning that HF is being used. Store these in a hood, not on a lab bench.

2. Do not use chemicals from unlabeled containers. The need for adequate labeling extends far beyond the immediate requirements of the individual users, since they may not be present in case of fire or explosion, or when containers are broken or spilled. Also, they may no longer be associated with the laboratory years later when containers have deteriorated or otherwise lost their value. Prior to graduation each person must properly dispose of his/her waste or

unwanted chemicals. All useful chemicals should be reassigned to another person who will assume responsibility. Proper labeling is extremely important as it is impossible to dispose of unlabeled chemicals.

3. Do not pipet by mouth. Use a rubber bulb specifically designed for this purpose. Never taste or smell any chemical.

4. Clean spills immediately! Small spills may be safely handled by lab personnel familiar with handling precautions for that material. Spill kits are available in Room 230. EH&S has a special Hazardous Material Response Team and a fully equipped emergency vehicle to handle larger spills. If in doubt of your ability to handle the situation, evacuate the lab, close the door, and call 911 and explain the nature of the emergency.

5. Items that might cause thermal burns, such as furnaces or hot plates, must be posted with a "HOT" sign or other warning when in use but not attended.

6. Avoid direct contact with any chemical, what might be considered safe today may eventually be found to be harmful.

B. Mercury Spills

For small spills or well contained spills, gather mercury and put in a closed container (wear gloves). To pick up small amounts of Hg beads stuck in cracks, use sticky tape such as masking tape. EH&S has a specially filtered mercury vacuum to pick up larger spills. Never use a regular vacuum, the mercury will contaminate the vacuum and release large quantities of Hg vapor whenever it is used. EH&S has instrumentation to measure Hg levels and will assist with decontamination procedures.

C. Glassware

1. Use only Pyrex or shatterproof glassware.

2. Never use cracked or chipped glassware.

3. Insert tubing properly into stoppers (i.e., use lubricants such as a few drops of glycerine and always wear gloves).

4. Check with EH&S for information on proper disposal of broken glass, needles, and syringes. Each laboratory should have its own container for broken glass only. Broken glass that is contaminated with harmful materials must be disposed of separately: consult the department safety officer or the EH & S office for the proper procedure. Broken glass thermometers containing mercury should be treated in the same way as a mercury spill. These should never be thrown in the broken glass container or trash receptacle.

D. Equipment

1. Before using an instrument or machine, be sure you have been instructed and authorized by the person responsible for the equipment. Become familiar with potential hazards associated with the equipment, emergency shutdown procedures, as well as the operating procedures.

2. Check all electrical connections and mounting bolts before each use.

3. Check that all rotating parts are free to turn, and that there are no mechanical obstructions before starting.

4. Attach an "emergency shutdown card" to any piece of equipment left operating unattended outside normal working hours. This card should contain your phone number and all information that would be required by anyone who might be faced with the need to shut down the equipment.

5. Laboratory equipment is not to be placed in corridors.

a. Gas Cylinders

The following page contains a copy of the "Sleeping Giant" by Marshall Peterson A.M.A. which describes the characteristics and damage potential of a gas cylinder. You should read this for enlightenment.

1. Secure gas cylinders with a strap or chain to a stable object (preferentially a wall or a heavy lab bench), whether or not they are in use. Always leave the cap on when the tank is not being used.

2. Transport gas cylinders, with cap on, and use a proper cart.

A Sleeping Giant

I am a compressed gas cylinder. I weigh in at 175 pounds when filled.

I am pressurized at 2,200 pounds per square inch (psi).

I have a wall thickness of ≈ 1/4 inch.

I stand 57" tall.

I am 9 inches in diameter.

I wear a cap when not in use.

I wear valves, gages, and hoses when at work.

I wear many colors and bands to tell what tasks I perform.

I transform miscellaneous stacks of material into glistening ships and many other things - when properly used.

I transform glistening ships and and many other things into miscellaneous stacks of material - when allowed to unleash my fury unchecked.

I am ruthless and deadly in the hands of the careless or the uninformed.

I am too frequently left standing alone on my small bases, my cap removed and lost by an unthinking workman. Then I am ready to be toppled over, my naked valve can be snapped off, and all my power can be unleashed through an opening no larger than a lead pencil.

I am proud of my capabilities - here are a few of them:

I have been known to jet away faster than any dragster.

I smash through brick walls with the greatest of ease.

I fly through the air and reach a distance of half-a-mile or more.

I spin, ricochet, crash and slash through anything in my path.

I scoff at the puny efforts of human flesh, bone, and muscle to change my erratic course.

I can, under certain conditions, rupture or explode - you read of these exploits in the newspapers.

You can be my master only under my terms:

Full or empty, see to it that my cap is on straight and snug.

Never, repeat never leave me standing alone. Keep me in a secure rack or tie me so that I cannot fall.

TREAT ME WITH RESPECT - I AM A SLEEPING GIANT.

Marshall Peterson A.M.A.

3. Do not use an open flame near gas cylinders.

4. Never use grease or other lubricants on gauges or connections (This may form explosive mixtures with oxidizing gases).

5. Before using gas in an experiment, be sure there are no leaks in the system.

6. Learn directions for closing and opening valves. (All main valves close clockwise). Before connecting a non-toxic gas cylinder to a system, remove the valve cap and open the valve for an instant to clear the opening of particles or dirt. To turn on a system, open the main cylinder valve completely and open remaining valves successively further from the main cylinder. To shut down a system close the main cylinder first and close remaining valves in the order in which they were opened to avoid storing high pressure in the system.

7. Do not use adaptors to connect regulators. Use only regulators specified for the particular gas. Have all regulators inspected and serviced regularly. Regulators open by turning the handle clockwise, this increases the pressure in the system.

8. Only use regulators, pipes, and fittings specified for the type of gas you will be using. Hydrogen embrittlement may cause hazards such as leaks or ruptures. Consult the department safety officer to determine the correct materials for your application.

9. Do not locate gas cylinders near heat sources, like furnaces, where they may heat up and explode.

10. Familiarize yourself with the toxic properties and safety hazards of each gas you work with. Post any safety information that may pertain to others working in the lab.

11. Store oxygen cylinders and combustible gases separately.

b. Vacuum Systems

Mechanical vacuum pumps used in laboratories pose common hazards. These are the mechanical hazards associated with any moving parts and the chemical hazards of contaminating the pump oil with volatile substances and subsequently releasing them into the lab. A few guidelines will help in the safe use of these devices. Distillation or concentration operations

requiring large concentrations of volatile substances should be performed using a water aspirator. If a vacuum pump is required for lower pressures, the pump must be fitted with a cold trap to condense the volatiles. The output of the pumps should be vented to a hood or alternate exhaust system. The pump oil should also be replaced when it becomes contaminated and disposed of by the chemical waste disposal guidelines presented later in this manual.

1. Be certain that your vacuum system has a trap.
2. Use only containers that can withstand evacuation. When possible, tape containers to be evacuated and use a standing shield to guard against implosion.
3. Always close the valve between the vacuum vessel and the pump before shutting off the pump to avoid sucking vacuum oil into the system.
4. All moving belts on mechanical pumps must have a safety cover.

c. Distillations and Condensers

Superheating and sudden boiling frequently occur when distilling under vacuum. Therefore it is important that the assembly be secure and the heat be distributed evenly (i.e. with a heating mantle or liquid bath). A standing shield should be in place to guard against implosion. An additional thermometer should be inserted near the bottom of the distilling flask to warn of a dangerous exothermic reaction. After finishing a vacuum distillation, cool the system before slowly bleeding in air, since air may induce an explosion in a hot system. Be sure that hoses carrying cooling water are securely attached with hose clamps to prevent accidental floods. Glass joints should be secured with clips available from the stockroom to prevent accidental disconnection or disconnection caused by vapor build up.

d. Drying Ovens

Electric ovens are often used in laboratories for removing solvents or water from samples and to dry laboratory glassware. These ovens if not properly vented or used in a hood, discharge the volatile substances into the laboratory atmosphere which can accumulate in toxic concentrations. Small amounts of vapor can accumulate inside the oven and mix with the air to form explosive mixtures.

Ovens should not be used to dry any chemical known to possess toxic vapors or that might volatilize and pose an explosion hazard or acute chemical hazard unless special precautions have been taken to ensure continuous venting to a hood. Organic compounds should not be dried in ovens whose heating elements or temperature controls (which may produce sparks) are exposed to

the interior atmospheres. It is recommended to have blow out panels in the rear of a drying oven so that an explosion will not blow the door and contents into the lab. Bimetallic strip or alcohol thermometers rather than mercury thermometers should be used in ovens.

E. Removal of Organics (Volatiles) in Furnaces

When removing binders or other organic substances from ceramic powders prior to sintering, one must observe similar precautions to those discussed for drying ovens. During decomposition, binders break down into shorter chain molecules and volatilize from the sample. These decomposition products often contain carbon monoxide as well as other toxic gases. If not properly vented, these gases may pose acute or chronic toxicity hazards to people in the lab and they can also form explosive mixtures when combined with the furnace atmosphere. Prior to burning out any organic material in a furnace one should estimate the chemical composition of possible decomposition products and ensure the heating cycle and furnace atmosphere are properly controlled so that the explosive limits of the by-products are not reached. The CRC Handbook of Chemistry and Physics lists explosion limits for some substances. If in doubt contact EH&S for additional assistance. Never fire Pb or Cd containing materials in unvented furnaces.

F. Transporting Chemicals

When chemicals are carried by hand, they should be placed in a carrying container or acid-carrying bucket to protect against breakage and spillage. When they are transported on a wheeled cart, the cart should be stable under the load and have wheels large enough to negotiate uneven surfaces without tipping or stopping suddenly. Provisions for the safe transport of small quantities of flammable liquids include a) the use of rugged pressure-resistant, non-venting containers, b) storage during transport in a well-ventilated vehicle, and c) elimination of potential ignition sources. Chemicals should not be carried in open containers in hallways or elevators where they may be spilled.

G. Chemical Storage

Every chemical should have a specific storage space. They should not be stored on counter tops where they can be knocked over or in hoods where they interfere with proper air flow. Flammable liquids should be stored in ventilated storage cabinets. Flammable liquids should not be stored near ignition sources or in areas where accidental contact with strong oxidizing agents is possible. Oxidizing agents include: chromic acid, permanganates, chlorates, perchlorates, and peroxides. All chemicals must be properly labeled giving the chemical name, name of owner, date of purchase, type of hazard and any emergency procedures.

V. CHEMICAL HAZARDS AND SAFETY PROCEDURES

The first step in using any chemical should be a review of the material safety data sheet supplied by the manufacturer, available from the department's safety coordinator, [illegible]. Pay specific attention to the potential hazards and safety equipment required for working with the material. Be familiar with the proper emergency procedures recommended for the chemical in case of accidental exposure.

A. Unattended Chemical Reactions

Take great care in setting up chemical reactions that are to be left unattended for any period of time. Note that unattended operation should be avoided if at all possible. The possible hazards that might arise from failure of a heating mantle (overheating), failure of a water cooling system (hose becoming disconnected or bursting), and failure of an exhaust (if flammable solvents or toxic gases are involved), are obvious points to check before leaving a reaction unattended. Any reaction that is left unattended should be clearly labeled as to the nature of the reaction and its components, the possible hazards (i.e., poisonous vapors), and the name and phone number of the experimenter. A notice describing the nature of the unattended experiment, emergency procedures, and who to contact in case of emergencies should be posted on the outside of the door to the laboratory in which the experiment is being conducted.

Before beginning a chemical reaction the experimenter should have an idea of how it will proceed. Thus, ice baths can be ready if it is exothermic, a vent is available if gases are generated, automatic shutdown incorporated in the event of loss of electrical power, cooling water, etc. The experimenter should also notify his/her advisor that the experiment will be running overnight.

B. Toxic Hazards

Researchers should be aware of the toxic hazards of the materials they are using, and those being used by others in their vicinity. Toxic materials may enter the body through the skin, inhalation, and/or ingestion. Care should be taken to prevent these means of entrance when handling toxic materials. A large number of common substances are acute respiratory hazards and should not be used in a confined area in large amounts. They should be used only in a hood. Some of these include: ammonium hydroxide, carbon monoxide, chlorine, fluorine, hydrochloric acid, hydrogen sulfide, and sulfur dioxide. These may form as by-products of certain reactions. Control of these by-products should be part of the experimental procedure.

C. Acids and Bases

Acids and bases are found in most laboratories since there are a variety of applications for them. Three important hazards are associated with acids and bases: chemical burns suffered from spills, inhalation of caustic vapors, and fires or explosions caused by strongly exothermic reactions occurring when strong acids are diluted rapidly. Strong bases may often cause more severe burns than acids as they don't often provide a warning, such as a burning sensation until damage to the skin has already occurred.

1. Always dilute acids by adding them to water and not vice versa.
2. Use dilute acids and bases whenever possible.
3. Keep bottles of strong acids and bases closed when not in use since they can react with moisture in the air to form caustic fumes.
4. If acids or bases are accidentally splashed in the eye or on the skin, flush with water immediately, continue flushing for 15 minutes, and call for help.

Hydrofluoric Acid: Hydrogen fluoride (HF) is a very serious hazard since both its gas and solutions are extremely toxic and it is rapidly absorbed through the skin without immediate warning (such as a burning sensation), but causes long term excruciating pain and burns which take a long time to heal. Prompt removal of contaminated clothing while the injured person is being flushed with water is essential. Continuous flushing with cool water is vital until any whitening of the tissue has disappeared. Cover the exposed area with wet, iced cloths and get immediate medical help. Do not apply any ointments. In all cases of contact with HF obtain medical aid. Simple flushing with water does not remove HF deep in the tissues and additional treatment is required.

Perchloric Acid and Perchlorates: Cold perchloric acid has the properties of a strong acid. When hot it is also a strong oxidizing and dehydrating agent. It becomes unstable with time and will detonate under shock. Perchlorate compounds will often explode from heating, or from contact with flame, by impact, or friction, or spontaneously. Perchloric acid forms explosive compounds with both organic and inorganic chemicals. Because of this, it must be used in a special ventilation hood equipped with water spray and wash down in which no other types of chemical reactions have ever been vented, and which is not lubricated with organic lubricants. It is imperative that no one attempts to store or use perchloric acid or perchlorate compounds without the prior knowledge, instruction, and supervision or approval of your advisor/supervisor. A safety review by the safety chairman and selected faculty prior to experimentation is recommended.

D. Organic Solvents

Many organic solvents possess harmful vapors or pose health hazards because they can be easily absorbed through the skin. Most solvents are quite volatile and the vapors are flammable. Always refer to the MSDS of a solvent before using it to become aware of the hazards, safety precautions, and emergency procedures associated with that specific solvent. Always store them according to the guidelines for storage of flammable liquids. A few examples of the hazards of some common solvents are provided below, but this list is by no means complete.

Acetone Possesses toxic and flammable vapors. Use proper ventilation, safety glasses, and gloves. Store in a flammable liquids storage area.

Methanol Possesses harmful vapors that can cause dizziness, central nervous system depression, and shortness of breath. Severe exposure can lead to coma and eventually death. Less severe exposure can cause blurring of vision, conjunctivitis, headaches, gastrointestinal disturbances, and definite eye lesions. Methanol should be used in a ventilation hood and neoprene gloves should be worn.

Benzene Carcinogenic. Chronic poisoning can occur by inhalation of relatively small amounts over a long time. Can also be absorbed through the skin. Vapors are flammable and it should be stored in a flammable liquids storage area.

Ethers Ethyl ether, isopropyl ether, dioxane, tetrahydrofuran and many other ethers tend to absorb and react with oxygen from the air to form unstable peroxides which may detonate with extreme violence when they become concentrated by evaporation or distillation, when combined with other compounds that give a mixture that can be detonated, or when disturbed by unusual heat, shock or friction (sometimes as little as unscrewing the bottle cap). This class of compounds should be avoided if there is a safer alternative. It is generally recommended that ethers which will form peroxides should be stored in full, airtight, amber glass bottles, preferably in the dark, or in metal containers. Although ethyl ether is frequently stored under refrigeration (explosion proof), there is no evidence that refrigerated storage will prevent formation of peroxides. Furthermore, leaks can result in explosive mixtures even in refrigerators, since the flash point of ethyl ether is -45°C (-49°F).

E. High Energy Oxidizers

Very small amounts of strong oxidizers (0.25g) can result in severe explosions and must be handled with the proper protective equipment, such as protective clothing, leather gloves and face shields. Larger amounts require special procedures involving explosion barriers.

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F. Powders

Most ceramic materials are considered inert with the human body however submicron particles in the lungs may cause respiratory irritation. Whenever working with fine powders correct respiratory protection is recommended. Cloth dust masks available in the stockroom are not appropriate for work with extremely fine powders. Some powders such as SiO_2, cause lung diseases such as silicosis. BeO and PbO are considered extremely toxic and must be handled with great care. If possible use powders in a hood so as to not contaminate the laboratory. The specific requirements for each powder are generally listed on the MSDS. Some fine powders are pyrophoric and may explode when dispersed in air.

G. Whiskers and Fibers

Since the cancer causing nature of asbestos was discovered, other mineral and ceramic fibers are under suspicion for their health hazards. It is not well known whether this health risk involves a chemical or physical reaction in the body. Fibers and whiskers must be handled with care so that they may not be inhaled or brought into contact with the skin.

VII. RADIATION HAZARDS

A number of acute and long term effects on humans have been related to exposure fror various types of ionizing radiation. Radiation hazards arise when using radio-isotopes, lasers ray generators and plasma torches. Each is hazardous in a unique way. A thorough knowled the device or the isotope which is to be used is mandatory. The precautions vary widely. Information pertaining to the particular hazard should be obtained from the faculty or research member or technician in charge of the equipment prior to use,

However, several precautionary procedures should always be followed:

A. Radioactive Materials

1. All work with radioactive material or radiation producing equipment must be registered wi the Health Physics Office. All persons using radioactive material and x-ray machines mus instructed in the potential hazards and the necessary safety precautions. Training sessions offered regularly by the Health Physics Office and include a written exam to demonstrate t the personnel have been adequately instructed.

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2. Do not wear another person's dosimeter or allow another person to wear yours.

3. Return your old dosimeter to the Health Physics Office immediately after receipt of new dosimeter (every 3 months) whether you used it or not. You will be charged for dosimete returned more than 10 days after receipt of the exchange dosimeter and for lost or damage dosimeters.

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4. Review with the Health Physics Office any potential exposures to non-ionizing radiation s as ultraviolet, visible, infrared and microwave radiation.

5. Clearly mark areas in which lasers, ultraviolet, or high intensity light sources are in use.

6. Wear eye protection appropriate to the type of radiation being used when working with th sources.

7. Remember that electron microscopes (SEM's and TEM's) are x-ray sources.

B. X-ray Equipment:

1. Under no circumstances should any part of the body be placed directly in primary x-ray beams.

2. Whenever possible turn the x-ray beam off before working on the machine. If this cannot be done, double check to be sure that the shutter on the port involved is closed.

3. Never align samples with the eye in such a position that it might be exposed to the primary beam.

4. Do not defeat any interlock devices, e.g. wiring shutters in the open position.

5. Do not use any x-ray machine that is not working properly.

6. Wear any required personnel monitoring devices at all times while using the x-ray machine.

7. Have the radiation levels around the x-ray machine checked anytime a configuration is used which has not previously been surveyed.

8. Report any suspected overexposures to the Health Physics Office immediately.

9. Do not depend upon lead foil or sheets for permanent shielding. Shields should be constructed of more durable materials. If lead is to be used it should be as a liner inside brass or some other material.

10. Remember the additional high voltage hazard associated with x-ray machines.

C. Lasers

There are many types and intensities of lasers and therefore only general guidelines are given.

1. Never look directly at the beam or pump source.

2. Never view the beam pattern directly; use an image converter or other safe, indirect means. To decrease reflection hazard, do not aim by looking along the beam.

3. Do not allow any object which could cause specular reflections in or along the beam. Such as spherical buttons, screw heads, or jewelry.

4. Keep a high general illumination level where lasers are in operation to cause contraction of pupils and reduced hazard.

5. Always wear goggles that offer protection against specific wavelength of the laser in use.

6. Post warning signs outside and inside the laboratory to warn of potential hazards. Clearly mark any areas where laser beams are in use.

D. Ultraviolet Lamps:

1. All radiation of wavelengths shorter then 3500 Å should be considered dangerous.

2. Protective safety glasses with UV absorbing lenses should be worn when the eyes may be accidentally exposed.

3. Skin exposed to UV radiation can receive painful burns , analogous to sunburns and should be protected.

VIII. ELECTRICAL HAZARDS AND SAFETY PROCEDURES

While electricity is in constant use by the researcher, both within and outside the laboratory, significant physical harm or death may result from its misuse. With direct current, a person can detect a "tingling" feeling at 1 mA and the median "let-go" threshold (the current at which he cannot release the conductor) is 76 mA. For 60 Hertz alternating current, the values are 0.4 mA and 16 mA, respectively. Women are more sensitive to the effects of electrical current; approximately 2/3 of the current is needed to produce the same effect. Higher currents produce respiratory inhibition, then ventricular fibrillation, and ultimately cardiac arrest.

If an electrical hazard is suspected, the device in question should be disconnected immediately and the cause ascertained by a person competent in such matters. Work on electrical

devices should be done only after the power has been shut off in such a manner that it cannot be turned on accidentally. Since malfunctioning equipment may contain shorts, merely turning off the equipment is not sufficient to prevent accidents. Equipment should be unplugged before being inspected or the circuit the equipment is wired to deactivated by putting the circuit breaker in the off position or removing the fuse. Equipment wired to a safety switch should be turned off at the safety switch. Internal current-carrying devices such as capacitors must be discharged.

The following is a list of rules for working with electrical equipment:

1. Turn off the power to equipment before inspecting it. Turn off circuit breakers or unplug the equipment. To turn off a safety switch, use your left hand (wear insulating gloves made of leather or heavy cotton), turn your face away from the box, and pull the handle down. Circuits may discharge violently when being turned on or off and the cover to the junction box may be blown open.

2. Use only tools and equipment with non-conducting handles when working with electrical devices.

3. All current transmitting parts of any electrical devices must be enclosed.

4. When checking an operating circuit keep one hand either in a pocket or behind back to get the extra style points from the Russian judge (to avoid making a closed circuit through the body).

5. Maintain a work space clear of extraneous material such as books, papers, and clothes.

6. Never change wiring with circuit plugged into power source.

7. Never plug leads into power source unless they are connected to an established circuit.

8. Avoid contacting circuits with wet hands or wet materials.

9. Wet cells should be placed on a piece of non-conducting material.
10. Check circuits for proper grounding with respect to the power source.

11. Do not insert another fuse of larger capacity if an instrument keeps blowing fuses - this is a symptom of a problem requiring expert repairs. If a fuse blows, find the cause of the problem before putting in another one.

12. Keep the use of extension cords to a minimum and cords as short as possible. Tie off excess cord out of pathways to avoid trip hazards.

13. Do not use or store highly flammable solvents near electrical equipment.

14. Multi-strip outlets (cube taps) should not be used in place of permanently installed receptacles. If additional outlets are required have them installed by an electrician.

15. Keep access to electrical panels and disconnect switches clear and unobstructed.

A. Static Electricity and Spark Hazards:

Sparks may result in explosions in areas where flammable liquids are being used and therefore proper grounding of equipment and containers is necessary. Some common potential sources of sparks are:

1. The making and braking of an electrical circuit when the circuit is energized.
2. Metal tanks and containers.
3. Plastic lab aprons.
4. Metal clamps, nipples, or wire used with nonconducting hoses.
5. High pressure gas cylinders upon discharge.

IX. CRYOGENIC SAFETY

1. When using a liquid nitrogen cold trap, charge the trap only after the system is pumped down. Since the boiling point of liquid nitrogen is -196°C and the boiling point of liquid oxygen is -183°C, liquid oxygen as well as volatile organic substances could condense in the cold traps. These mixtures may explode. When shutting down a system, charge the lines with nitrogen gas to prevent oxygen from entering the system.

2. Do not mix any organic material with liquid nitrogen for the reasons explained above. Wood and asphalt saturated with liquid oxygen has been known to explode when subjected to mechanical shock.

3. Handle any liquefied gas carefully: at extremely low temperatures it can produce an effect on the skin similar to a burn caused by a hot object. Eyes should be protected with a face shield or safety glasses. Gloves should be worn.

4. Stand clear of the boiling and splashing liquid and its issuing gas. Should any liquefied gas contact the skin or eyes, immediately flood that area of the body with large quantities of unheated water and then apply cold compresses.

5. Large quantities of liquid nitrogen can condense oxygen and thus remove it from the air. Use liquid nitrogen only in a well ventilated area so that the ambient oxygen concentration does not drop lower than 16% (the same applied to liquid helium).

6. High pressure gas hazards are always present when cryogenic fluids are used as they are usually stored at their boiling point. Never obstruct the vent valve on cryogenic containers.

An excellent reference which is strongly recommended for anyone working with cryogenic materials, is: Safety with Cryogenic Fluids, Michael G. Zabetakis, Plenum Press, New York, NY, 1967.

X. FIRE SAFETY RULES

A. Precautionary Procedures

1. Know the location of fire exits, fire alarms, and fire extinguishers. Appendix A of this manual contains a floor plan which pinpoints the location of each of these in MRL. Each laboratory should be equipped with extinguishers. Fire extinguishers are primarily for use on fires in their incipient stages. Make it your business to learn about the proper use of fire extinguishers. See the following Guide to Classes of Fires.

2. Keep all fire doors closed at all times.

3. Do not block access to fire escape routes.

4. Neatness prevents many fires. Fire spreads much faster when it has cluttered waste materials to feed on. Oily rags, waste or papers improperly stored are common causes of spontaneous combustion. Store these materials in covered metal containers. Overloaded electrical circuits are potential fire hazards. Flammable vapors can ignite far away from their source and thus should be vented properly.

B. Emergency Procedures

1. If a fire starts, activate the nearest fire alarm box then call for assistance from a safe location by dialing 911. If the fire is not too large, confine and try to extinguish it with the proper type of extinguishers in the lab. Never jeopardize your personal safety in trying to extinguis a fire.

2. If there is no injury, and the fire is contained in a vessel, it can usually be suffocated by covering the vessel with a non-flammable object. Do not use towels or clothes. Remove nearby flammable materials to avoid possible spread of fire. If the fire is over an area too large to be suffocated quickly and simply, abandon the fire.

3. If evacuation is necessary, and if time allows, shut off power to any equipment. Shut off ga or other open flames. Turn off hot plates and main gas valves.

4. If your clothes ignite, "stop, drop and roll," to smother the flames. Do not run: running only intensifies the flames. When fire blankets are readily available, use them to wrap around yourself to aid in putting out the fire. Call for help.

5. Exit from the building via staircases; do not take elevators. Remove any objects that may be obstacles in passageways or to fire doors. Do not return to the building unless permitted to do so by the Fire Department.

Electrical Fires

1. Turn off power source at the breakers or the junction box and unplug.
2. Use CO_2, or dry chemical extinguisher to put out fire. Never use water.
3. When fire is extinguished check circuit to determine cause.
4. Do not turn on circuit until cause of fire has been established and the fault corrected.
5. Report fire to Safety Office.

XI. GUIDE TO CLASSES OF FIRES AND METHODS OF EXTINGUISHMENT

Class A Fire

Material: Wood, paper, textiles and other ordinary combustible materials.

To extinguish:
Pressurized water
Multi-purpose dry chemical
Halon

Class B Fire

Material: Flammable liquids: oils, solvents, grease, paint, etc.

To extinguish:
BC dry chemical, regular
Carbon dioxide (if fire is contained in a small area).
Multi-purpose dry chemical
Halon

Class C Fire

Electrical Fires

To extinguish:
Carbon dioxide
Halon
BC dry chemical, regular. This is effective, but will destroy electronic gear.
Multi-purpose dry chemical. This is effective, but will destroy electronic gear.

Class D Fire

Material: Metals: Magnesium, Aluminum, Sodium, Potassium, Zirconium, Titanium etc.

To extinguish:
Special metal extinguishers
The ordinary extinguishers found in the building should not be used on metal fires because a violent reaction may result.

XII. REFERENCES

The Merck Index, Merck Pharmaceutical Company.

Dangerous Properties of Industrial Materials, 4th ed., N. Irving Sax, ed., Van Nostrand Pub. Co., New York, 1978.

Toxic and Hazardous Industrial Chemicals Safety Manual, International Technical Information Institute, 1978.

Prudent Practices for Handling of Hazardous Chemicals in Laboratories, National Academy Press, Washington, D.C., 1981.

Prudent Practices for Disposal of Hazardous Chemicals from Laboratories, National Academy Press, Washington, D.C., 1983.

Occupational Health Guidelines for Chemical Hazards, NIOSH-OSHA, Jan., 1981.

Materials Safety Data Sheets published by chemical manufacturers are available through the safety office.

Safety in Academic Laboratories, American Chemical Society, 1155 16th St. N.W., Washington D.C., 1979.