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INTRODUCTION

PURPOSE

The purpose of the Division of Mathematics and Natural Science Safety Manual is to provide guidelines and policies that will promote a safe and healthy work environment for all personnel and students within the division, for all visitors to the division, and for all other persons who have reason to be working in divisional laboratories. It is the intent that the policies and guidelines presented in the manual ensure compliance with federal, state and local regulations.

OVERVIEW OF REGULATORY INFORMATION

A large number of regulations affect laboratories. While the Final Rule on Occupational Exposure to Hazardous Substances in Laboratories, **29 CFR 1910.1450**, is the primary OSHA (Occupational Safety and Health Act) regulation concerning work with chemicals in laboratories, there are also other closely related OSHA regulations directly affecting laboratories. Besides OSHA standards, the Environmental Protection Agency governs the management of hazardous wastes and protection from radiation hazards is regulated by both OSHA and the Nuclear Regulatory Commission. In addition components of the Toxic Substances Control Act apply to research laboratories.

Occupational Exposure to Hazardous Substances in Laboratories, 29 CFR 1910.1450

The final rule on Occupational Exposure to Hazardous Chemicals in Laboratories, **29 CFR 1910.1450**, was released by the Occupational Safety and Health Administration (OSHA) on January 31, 1990 and is commonly referred to as the “Laboratory Standard”. The standard applies to all employers that are engaged in the laboratory use of hazardous substances.

The main requirement of the standard is that employers develop and implement a Chemical Hygiene Plan (CHP), which is a written program that must be capable of protecting employees from the health hazards associated with chemicals used in the workplace. It is essential that employee exposures are maintained below the airborne permissible exposure limits adopted by OSHA. The **Division of Mathematics and Natural Science Chemical Hygiene Plan** is found in the next section of this manual.

The Lab Standard supersedes the requirements of all other health standards in 29 CFR part 1910 subpart Z except for the requirement limiting exposures to below the

Permissible Exposure Limits (PEL's). Where the PEL's are routinely exceeded, exposure monitoring and medical surveillance are required. Also the prohibition of eye and skin contact specified by any OSHA health standard must be observed.

While the Lab Standard supersedes OSHA health standards other standards not specifically addressed remain applicable. Subpart H of 29 CFR part 1910, which addresses physical hazards such as compressed gases, flammable liquids, and combustible liquids remains in effect for laboratories. In addition, Subpart G which addresses ionizing and non-ionizing radiation is applicable along with the General Duty Clause explained below.

General Duty Clause, 29 USC 6545(a) and (b) 182.653, Subdiv.2

The purpose of the General Duty Clause is to assure that the workplace is free from recognized hazards that are causing or likely to cause serious physical harm to employees. The General Duty Clause must not be used in cases where a specific standard exists and may not be used to set a higher level of protection than is provided for in a standard. However any serious hazard not covered by a specific provision of OSHA may be subject to a citation under the General Duty Clause.

The General Duty Clause can be cited when:

- employees were exposed to a hazard
- the employer failed to keep the workplace free of the hazard or should have recognized the hazard based on industry standards or national consensus standards
- the hazard is likely to cause death or serious physical harm
- a feasible method is available to correct the hazard

Hazard Communication (Right-To-Know) Standard, 29 CFR 1910.1200

The Hazard Communication Standard applies to employees who are routinely exposed to hazardous substances in a non - laboratory setting.

Air Contaminants- Permissible Exposure Limits (PEL's), 29 CFR 1910.1000

Permissible Exposure Limits are regulatory standards set by OSHA. One of the requirements of the Laboratory Standard is that Permissible Exposure Limits not be exceeded for any OSHA health standard. The **PEL's** for air contaminants set by OSHA are listed in **29 CFR 1910.1000**.

Hazardous Materials, 29 CFR 1910.111

While the Laboratory Standard exempts laboratories from most provisions of 29 CFR 1910 subpart Z, other subparts including H, Hazardous Materials apply. Subpart H

provides protection against the hazards of compressed gases, flammable and combustible liquids, explosives and anhydrous ammonia. Also applicable are the Uniform Fire Code and the National Fire Protection Association Standards.

Personal Protective Equipment, 29 CFR 1910.132-138

Subpart I of 29 CFR parts 1910 ensures that employees are provided with and have appropriate training in the use of personal protective equipment including eye protection, face protection and respiratory tract protection. Also applicable are the American National Standard Institute (ANSI) Standards.

Radiation Hazards

Protection from the hazards associated with radiation including ionizing radiation, non-ionizing radiation and radioactive materials is required by several regulations. **OSHA 29 CFR 1910.96, 29 CFR 1910.97** along with the Atomic Energy Act, the Energy Reorganization Act, and the Nuclear Regulatory Commission all establish standards of protection, exposure limits, and licensing requirements.

Hazardous Waste Management –Environmental Protection

The Environmental Protection Agency has several regulations on managing hazardous wastes. Included are manifesting rules, storage rules, record keeping requirements, training requirements and emergency response requirements. Also applicable is **40 CFR 260 to 399 and 49 CFR 100 to 199** (Department of Transportation Rules).

Toxic Substances Control Act

The purpose of the Toxic Substances Control Act (TSCA) is to control new or existing chemicals that may present unreasonable health risks. The part of TSCA that directly affects research laboratories is part 8c, which includes record keeping requirements for significant adverse reaction allegations.

Fire Protection and Safety

Fire protection and fire safety are addressed in the OSHA standards **29 CFR 1910.157 and 1910.138**. OSHA requires that personnel be trained in fire safety and that available fire fighting equipment is maintained.

Chemical Spill Response

Chemical spill response is addressed by OSHA in **29 CFR 1910.120**, the Hazardous Waste Operations and Emergency Response Standard and in the Lab Standard, **29 CFR 1910.1450**.

SAFETY MANUAL ORGANIZATION

The Chemical Safety Manual provides guidelines for safely working in the laboratory. The manual describes safe work practices, and when and how to properly use engineering controls, personal protective equipment and other safety equipment. Following the guidelines presented in the manual will ensure that all of the provisions of the appropriate federal, state and local regulations will be satisfied.

The Laboratory Standard requires that all personnel are protected from the health hazards associated with hazardous chemicals in the laboratory. Research and academic laboratories differ from general industry in the manner in which hazardous substances are used and handled. Laboratory workers are generally exposed to a larger variety of hazardous substances but for shorter duration. Therefore, the approach adopted in providing protection from the health hazards associated with exposure to hazardous chemicals is to follow standard working procedures for classes of hazardous substances rather than for specific substances.

Hazardous chemicals are those substances, which are either physical hazards or health hazards. The OSHA Laboratory Standard defines health and physical hazards as:

health hazards

substances for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed individuals and include:

- carcinogens
- toxic or highly toxic agents
- reproductive toxins
- irritants
- corrosives
- sensitizers
- hepatotoxins
- neurotoxins
- agents which act on the hematopoietic system
- agents which damage the lungs, skin, eyes, or mucous membranes

physical hazards

chemicals for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water-reactive.

OSHA considers select carcinogens, reproductive toxins, and substances that have a high degree of acute toxicity to be **particularly hazardous substances**. Additional

precautions beyond the general safety practices are required when working with particularly hazardous substances.

There are approximately 700 substances for which OSHA has established Permissible Exposure Limits (**PEL's**). The **PEL's** are regulatory standards (29 **CFR 1910.1000**) established to protect workers from overexposure to airborne toxic and hazardous substances. Some substances may also have action levels. An action level is an airborne concentration below the **PEL** at which certain activities such as exposure monitoring and medical surveillance must occur. Compounds with action levels include benzene, arsenic, acrylonitrile, cadmium, ethylene oxide, lead, formaldehyde, vinyl chloride, and DBCP (1,2 -dibromo -3- chloropropane).

The Laboratory Standard requires that:

- the **PEL** for regulated substances not be exceeded;
- for substances that have action levels, requirements for medical and exposure monitoring become effective; and
- for 'select carcinogens', reproductive toxins and substances with a high degree of acute toxicity, additional protective measures beyond general laboratory practices must be considered.

The Chemical Safety Manual is organized in several sections. The first section consists of the general safety guidelines to be followed for the procurement, distribution and storage of chemicals. Next there are sections concerning the proper use and choice of personal protective equipment and engineering controls. Standard operating procedures for working with the various classes of hazardous substances comprise several sections. The appropriate procedure or procedures are to be followed when work involves hazardous materials. Next, there is a section on working with laboratory equipment. Finally chemical spill response is addressed.

THE CHEMICAL HYGIENE PLAN

The provisions of the Chemical Hygiene Plan ensure that employees are protected from the health hazards associated with hazardous chemicals used in the workplace. It is the intent that employee exposures to OSHA regulated substances are maintained below the permissible exposure limits (PEL's) specified in **29 CFR 1910, Subpart Z**, Toxic and Hazardous Substances.

INTRODUCTION

Purpose

The Chemical Hygiene Plan is a written program describing safe work practices and procedures, the use of engineering controls such as fume hoods, and the use of personal protective equipment. The practices and procedures outlined in the plan are intended to ensure that employee exposures to OSHA regulate substances are maintained below the permissible exposure limits.

Scope and Application

The Laboratory Standard applies to all persons engaged in the laboratory use of hazardous chemicals where "**Laboratory Use of Hazardous Chemicals**" refers to the handling of hazardous chemicals meeting the following criteria:

- chemical manipulations are carried out on a "laboratory scale"
- multiple chemical procedures or chemicals are used
- the procedures are not part of a production process
- protective laboratory practices and equipment are available to minimize the potential for exposure to hazardous chemicals

Laboratory Scale means work with substances in which the containers used for their handling are designed to be manipulated by one person.

Hazardous Chemical is a chemical for which there is statistically significant evidence that acute or chronic health effects may occur in exposed persons.

According to the definitions set forth in the standard, the **Chemical Hygiene Plan** applies to all personnel in the Division of Mathematics and Natural Sciences who in the course of his or her assignments may be exposed to hazardous chemicals. Also it is the policy of Belmont Abbey College that laboratory students will be given training commensurate with the level of hazard associated with their laboratory work.

Chemical Hygiene Plan Review

As required by the Laboratory Standard, the **Chemical Hygiene Plan** will be reviewed annually to ensure that adequate protection from exposure to hazardous substances is provided. If necessary the Chemical Hygiene Plan will be updated on an annual basis.

RESPONSIBILITY

The responsibility for chemical hygiene rests at all levels within the Division of Mathematics and Natural Science including the Department Chairpersons, Laboratory Supervisors, the Chemical Hygiene Officer and all other personnel and students.

Divisional Chairperson

The Divisional Chairperson has the responsibility and the authority to see that the Chemical Hygiene Plan is written, updated, and implemented. In addition, the Divisional Chairperson appoints the Chemical Hygiene Officer in accordance with the definition provided in **paragraph (b) of 29 CFR 1910.1450**

Chemical Hygiene Officer

The Chemical Hygiene Officer assists the chairperson with the development and implementation of the Divisional Chemical Hygiene Plan (CHP). The Chemical Hygiene Officer provides advice and assistance to laboratory supervisors with regard to the training of personnel and the implementation of the CHP. The Chemistry Safety Committee is chaired by the Department's Chemical Hygiene Officer.

Laboratory Supervisors

Faculty members are responsible for the safety and health of all personnel of and visitors to their laboratories.

The primary responsibility of the supervisor is to implement the Divisional Chemical Hygiene Plan and ensure compliance with the OSHA Laboratory Standard. The supervisor must ensure that all personnel receive chemical hygiene training, follow all chemical hygiene rules and must ensure that the appropriate protective equipment is available and properly functioning. In addition the supervisor is responsible for assigning designated areas for work with particularly hazardous substances, arranging for any environmental monitoring and any necessary medical consultations or examinations. The supervisor should also conduct regular chemical hygiene inspections.

In a given laboratory there may be specific hazardous situations that are not covered by the Chemical Hygiene Plan. In these cases it is the responsibility of the supervisor to evaluate the hazards and develop any additional standard operating procedures. The standard operating procedures must meet the provisions of the Laboratory Standard.

Employees, Staff and Research Personnel

Employees, as defined by the Chemical Hygiene Plan, are those paid staff under the direction of the Chairperson, as defined by the Plan. Employees not under the direction of the Supervisor, but who are in an area under the direction of the Chairperson, are also subject to the Chemical Hygiene Plan and the standard operating procedures in effect in that area

It is the responsibility of employees and other personnel to follow the procedures outlined in the Chemical Hygiene Plan and all standard operating procedures developed under that plan. These include the following:

1. Understand and follow all standard operating procedures.
2. Understand all training received.
3. Understand the function and proper use of all personal protective equipment. Wear personal protective equipment when mandated or necessary.
4. Report, in writing to your supervisor, any significant problems arising from the implementation of the standard operating procedures.
5. Report to your supervisor and the Divisional Chemical Hygiene Officer all facts pertaining to every accident that results in exposure to toxic chemicals, and any action or condition that may exist that could result in an accident. Prepare written reports describing the circumstances of all serious accidents.
6. Contact your supervisor, or the Chemical Hygiene Officer if any of the above procedures are not clearly understood.

INFORMATION AND TRAINING

Information

All personnel covered by the Laboratory Standard are provided with and have access to the following information:

1. The contents of the OSHA standard, **29 CFR part 1910.1450**, Occupational Exposure to Hazardous Chemicals (the Laboratory Standard) and its appendices.
2. the **Divisional Chemical Hygiene Plan**
3. the **Permissible Exposure Limits** for OSHA regulated substances or for hazardous chemicals for which there is no applicable OSHA standard the recommended exposure limits.
4. the signs and symptoms associated with exposure to hazardous chemicals.
5. Material Safety Data Sheets.
6. a bibliography of other available reference material.

The information listed above is communicated to each employee during the training received at the employee's initial time of hire.

Training

All personnel in the Division of Mathematics and Natural Sciences required to receive chemical hygiene training at the time of their initial hire. The training is designed so that employees are apprised of the health hazards associated with hazardous chemicals in the workplace and measures that they can take to protect themselves from these hazards. If in the course of their work assignments new exposure situations arise, the employee will receive additional training. Also refresher training occurs on an annual basis after the review of the Chemical Hygiene Plan. All of the training includes the following components:

1. methods that can be used to detect the presence of hazardous chemicals.
2. physical and health hazards of chemicals in the laboratory.
3. measures employees can take to protect themselves from exposure to hazardous chemicals in the laboratory including standard work practices, emergency procedures, and the use of personal protective equipment.
4. applicable details of the Chemical Hygiene Plan.
5. basic toxicological principles including permissible exposure limits.
6. using an MSDS sheet.
7. an introduction to the handling of hazardous wastes.

GENERAL PROCEDURES FOR WORKING WITH CHEMICALS

All laboratory work with chemicals must be conducted in a safe manner. Laboratory workers must familiarize themselves with the **General Safety Guidelines** found in this manual. Adhering to good safety practices will minimize employee exposure to any adverse effects of laboratory chemicals.

When working with physical hazards as defined in the Laboratory Standard and outlined in Chapter One of this manual, laboratory workers must familiarize themselves with the **Standard Operating Procedures for Working with Physical Hazards**, of this manual. Included are:

- **Flammables and Combustibles**
- **Compressed Gases**
- **Cryogens and Liquefied Gases**
- **Oxidizers**
- **Pyrophorics**
- **Water Reactives**
- **Incompatible Chemicals**
- **Explosives**
- **Organic Peroxides**
- **Perchloric Acids**

When working with health hazards as defined in the Laboratory Standard and outlined in Chapter One, laboratory workers must familiarize themselves with the **Standard Operating Procedures for working with Health Hazard** of this manual. Included are:

- **Corrosives**
- **Irritants**
- **Sensitizers**
- **Toxins Affecting Target Organs**

STANDARD OPERATING PROCEDURES FOR WORKING WITH PARTICULARLY HAZARDOUS SUBSTANCES

When work involves the use of particularly hazardous substances as defined in the Laboratory Standard and outlined in Chapter One, the **Standard Operating Procedures for Working with Particularly Hazardous Substances** of this manual must be followed. Included are procedures for:

- **Select Carcinogens**
- **Reproductive and Developmental Toxins**
- **Compounds with a High Degree of Acute Toxicity**

All work with particularly hazardous substances must be:

1. conducted in a **designated area**.
2. All designated areas must have a highly visible sign.
3. Any particularly hazardous substances that generate dust, vapors or aerosols must be handled in a suitable containment device such as a **fume hood** or **glove box**.
4. Suitable gloves and eye protection shall be worn.
5. Inventories of particularly hazardous substances shall be maintained by all laboratories in the Division of Mathematics and Natural Sciences.
6. All contaminated waste shall be removed in accordance with the regulations applicable to **Hazardous Waste Management**.

SUBSTANCES DEVELOPED IN THE LABORATORY

For chemicals developed in the laboratory the following provisions shall apply:

1. If the composition of the newly developed substance is known and it is developed exclusively for use within the laboratory, the laboratory supervisor shall determine if it is hazardous. If the substance is determined to be hazardous, all laboratory workers shall receive Chemical Hygiene training as described in the Chemical Hygiene Plan.

2. For a chemical produced which is a byproduct whose composition is unknown, it shall be assumed that the substance is hazardous and all provisions of the Chemical Hygiene Plan must be met.
3. If the chemical produced is for another user outside of the laboratory, the laboratory supervisor shall comply with the Hazard Communication Standard, **29 CFR 1910.1200**, including the requirements for the preparation of Material Safety Data Sheets and labeling.

CHEMICAL PROCUREMENT, DISTRIBUTION AND STORAGE

The procurement, distribution and storage of chemicals is to be done in accordance with the procedures in the **Chemical Procurement, Distribution and Storage** section of this manual. In particular,

1. labels on containers of hazardous chemicals must not be removed or defaced.
2. Material Safety Data Sheets received with incoming chemicals will be maintained in the research stockroom of the Chemistry Department and made available to all personnel.
3. Flammable and combustible liquids shall be stored in accordance with the guidelines in, **Storing Flammable and Combustible Liquids**.
4. Compressed gas cylinders shall be stored in accordance with the guidelines in **Storing Gas Cylinders**.
5. All highly reactive materials shall be labeled, dated and inventoried when received as described in **Storing Highly Reactive Substances**.
6. All particularly hazardous substances shall be labeled, dated and inventoried when received as described in **Storing Particularly Hazardous Substances**.
7. Foodstuffs intended for the use of the laboratory will be identified with a label like:

NOT FOR CONSUMPTION FOR LABORATORY USE ONLY

PROTECTIVE APPAREL AND EQUIPMENT

All laboratories and areas in which chemicals are handled and used shall have access to:

- an easily accessible safety shower as described in **Safety Showers and Eye Wash Facilities**.
- an eyewash fountain as described in **Safety Showers and Eye Wash Facilities**.
- a fire extinguisher as described in **Fire Extinguishers**.
- protective apparel compatible with the required degree of protection for the substances being handled as described in Protective Apparel.

- telephone for emergency use.

In addition all personnel must wear eye protection and visitors at all times while in Divisional laboratories as described in **Eye Protection**.

Fume hoods or other containment devices as described in **Fume Hoods** shall be used:

- for all work involving "particularly" hazardous substances as defined in the Laboratory Standard.
- whenever the airborne concentration of a chemical is likely to approach the action level or **PEL (permissible exposure limit)**
- whenever flammable vapors are likely to approach one tenth of the lower explosion limit.
- whenever noxious odors are given off.

Gloves must be worn when working with particularly hazardous substances as described in the section, **Gloves**. Also, gloves are required when working with any substance on the OSHA PEL list carrying a "skin" notation.

MAINTENANCE AND INSPECTIONS

Protective equipment including eyewash fountains, safety showers and fume hoods shall be inspected on a regular basis and inspection records shall be kept as follows:

- fume hoods shall be inspected quarterly by a qualified person designated by the CHO, who shall also keep a record of inspection results.
- A person designated by the CHO, who shall keep a record of inspection results, shall inspect safety showers and eyewash facilities on a weekly basis.
- fire extinguishers shall be inspected and tagged annually and records kept on file by the director of Facilities Management.

During the maintenance of fume hoods, the fume hood must be cleaned out and if necessary decontaminated. The use of chemicals in the fume hood is restricted during maintenance. Fume hoods that are unsafe for use must be labeled with a "**DO NOT USE**" sign as described in **Fume Hoods**. Any modifications to hoods or duct work may not be made without approval.

Inspections of laboratories and areas where chemicals are handled and used shall be done annually. The results of inspections shall be communicated to the appropriate supervisor who will take any appropriate corrective action.

ENVIRONMENTAL MONITORING

Environmental monitoring will be conducted when an employee reasonably suspects that he/she has sustained an exposure to a hazardous chemical exceeding the PEL or action

level for a regulated substance. If this initial monitoring indicates that exposure over the action level or PEL is exceeded then the provisions of the relevant OSHA standard become effective. Monitoring may be terminated in accordance with the relevant standard. The Chemical Hygiene Officer will notify the employee of monitoring results within 15 working days of the receipt of the results.

MEDICAL CONSULTATION AND EXAMINATIONS

All employees working with hazardous chemicals have an opportunity to receive medical attention and any follow-up examinations deemed necessary by the examining physician under the following conditions:

- whenever any employee develops signs or symptoms associated with a hazardous chemical to which he/she may have been exposed to.
- where exposure monitoring reveals that an exposure level above the action level or PEL for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements is routinely exceeded.
- whenever an event resulting in the likelihood of exposure to a hazardous substance occurs, such as a spill, leak or explosion, the affected employee will be provided the opportunity for a medical consultation for the purpose of determining the need for a medical examination.

If immediate medical attention is needed, call 911. In case of minor injury report to Cox Road Urgent Care, 603 Cox Road, Gastonia, NC 28054, Phone (704) 852-9561.

When the need for a medical consultation or examination occurs, the Chemical Hygiene Officer shall be notified.

All medical consultations and examinations will be performed by or under the direct supervision of a licensed physician at no cost or loss of pay to the affected employee and will be performed at a reasonable time and place.

When employees are exposed to hazardous chemicals, the examining physician will be provided with the following information:

- the identity of the hazardous chemicals to which the affected employee may have been exposed.
- a description of the conditions under which the exposure occurred including any available quantitative exposure data.
- a description of the signs and symptoms that the employee is experiencing.

A written report will be provided to the College and will include:

- any recommendation for further medical follow-up.
- the results of the medical examination and any associated tests.

- any medical condition, which may be revealed during the course of the examination, which may place the employee at increased risk as a result of exposure to a hazardous substance found in the workplace.
- a statement that the employee has been informed by the physician of the results of the consultation or examination and any medical condition that may require further examination or treatment.

Any specific findings of diagnoses unrelated to occupational exposure will not be revealed in the physician's written report.

RECORDS

Records of the following activities must be maintained:

- records of exposure evaluation carried out by the Division of Mathematics and Natural Science will be kept by the CHO.
- all exposure evaluation raw data will be kept for one year and summary data for the term of employment plus 30 years.
- medical consultation and examination records will be kept by the College for the length of time specified by the appropriate standard. The minimum time is the term of employment plus 30 years.
- employee training shall be documented and the documentation will be kept by the CHO for five years.
- records of annual fume hood monitoring will be kept by the CHO and raw data will be kept for one year with summary data being kept for five years.
- accident reports will be maintained by the CHO.
- The laboratory supervisor shall keep inventory and usage records for particularly hazardous substances.

SIGNS AND LABELS

Signs and labels shall be used as a means of identifying hazards and emergency information. Prominent signs and labels of the following types shall be posted:

- emergency telephone numbers
- emergency exits.
- location signs for **safety showers, eyewash stations and first aid equipment.**
- identity labels on containers of **particularly hazardous substances, highly reactive materials, gas cylinders, and flammable and combustible materials.**
- identity labels on containers of **hazardous wastes.**
- signs indicating **Designated Areas** or areas where other special hazards exist.
- signs indicating **storage of highly reactive substances and storage of particularly hazardous substances.**

HAZARDOUS CHEMICAL WASTE DISPOSAL

Chemical wastes should be collected in suitable containers that are clearly labeled. Incompatible wastes shall not be mixed. Waste containers should be kept closed unless waste is being added or removed. Evaporation of chemicals is not an acceptable means of disposal. Measures shall be taken to avoid the accidental ignition of flammable and combustible wastes. Waste disposal should be scheduled periodically with a licensed chemical waste vendor; chemical wastes should not be stored indefinitely. Hazardous waste regulations may require specific labeling and limit accumulation times depending on the generator status of the community college.

All disposals shall be in accordance with Federal, State and local regulations. No hazardous waste, as defined by the EPA in 40 CFR 261, shall be disposed except at an EPA permitted facility. Other materials that may be hazardous but do not meet the definition of hazardous waste shall be disposed of in an environmentally responsible manner. Before any chemicals are disposed by way of sanitary sewer ("down the drain"), prior approval by the local wastewater treatment plant shall be granted. Students and other unnecessary persons shall not be present in the laboratory or disposal area during disposal of any chemicals. This includes either disposal by a licensed chemical waste vendor or sanitary sewer disposal by BAC personnel.

CHEMICAL SPILLS AND ACCIDENTS

Emergency responses for handling injuries, fires, the release of toxic materials and explosives and power outages are outlined under the **Emergency Action Plan in the Belmont Abbey Health and Safety Plan**. For chemical spills, the procedures for clean-up are found in Chemical Spills.

PRIOR APPROVAL

Laboratory workers are required to obtain prior approval for the use of the following hazardous substances:

- Arsine
- Boron trifluoride (gaseous)
- Carbon monoxide
- Carbonyl fluoride
- Chlorine pentafluoride
- Chlorine trifluoride
- Cyanogen chloride
- Diborane
- Dinitrogen tetroxide / nitrogen dioxide
- Fluorine
- Germane
- Hydrogen cyanide
- Hydrogen fluoride(anhydrous)
- Hydrogen selenide
- Hydrogen sulfide
- Oxygen difluoride
- Phosgene(gaseous)
- Phosphine
- Phosphorous pentafluoride
- Selenium hexafluoride
- Silane
- Silicon tetrafluoride
- Stibine
- Sulfur dioxide
- Sulfur tetrafluoride
- Tellurium hexafluoride

The prior approval process shall consist of a "request for approval" submitted by the principal investigator of the laboratory to the Divisional Safety Officer at least two weeks prior to the intended use. The criteria to use in determining when to submit a "request for approval" are:

1. A request must be submitted prior to the first time the substance is purchased or otherwise acquired. The substance must not be loaned or given to another research group without prior approval.
2. For existing inventory, a request must be submitted prior to the first use of the substance.

A request for approval shall include:

1. the identity and quantity of the substance to be used.
 2. the intended use.
 3. the possible hazards in the handling or storage of the substance.
 4. the safety precautions to be taken.
 5. the existing protective equipment and engineering controls.
 6. provisions for emergency handling of overexposure, chemical spills, and wastes.
- After a "request for approval" is received the Departmental Safety Officer will consult with appropriately qualified individuals . Recommendations concerning approval decisions will be sent to the Department Chairperson who will make all prior approval decisions.

The Departmental Safety Officer will maintain records of prior approval decisions.

THE SAFETY MANUAL

CHEMICAL PROCUREMENT, DISTRIBUTION AND STORAGE

PROCUREMENT

Before a substance is received information on the proper handling, storage, and disposal should be available. To ensure that this information is available:

1. No container of chemical or cylinder of gas shall be accepted by any individuals without an identifying label.
2. Labels on containers of hazardous substances must not be removed or defaced.
3. All Material Safety Data Sheets received with incoming chemicals will be maintained and made available to all personnel in the appropriate stockroom in the Division of Mathematics and natural Sciences.
4. All chemicals should be dated and inventoried when received.

DISTRIBUTION

There is great potential for accidents and overexposure to hazardous chemicals to occur when transporting chemicals from the stockroom to the laboratory and between laboratories. The following guidelines are intended to minimize the dangers associated with transporting chemicals.

1. When chemicals are hand carried they should be placed in a secondary container to protect from spillage and breakage.
2. When using carts to transport chemicals, each shelf must have sides that are high enough to retain the containers.
3. Corrosive liquids chemicals should be carried in resistant plastic containers.
4. Rugged, pressure-resistant, nonventing containers should be used for the transport of small quantities of flammable liquids.
5. Potential ignition sources should be eliminated when transporting flammable substances.
6. A hand truck should transport cylinders of compressed gas with the cylinder strapped in place.
7. The cover cap on gas cylinders should be left screwed on until the cylinder is in place and ready for use.

CHEMICAL STORAGE

Chemicals should be stored to minimize exposure to hazardous substances, chemical spills, the possibility of fire or explosions , and to minimize reactivity hazards. Many regulations affect the storage of a variety of substances including radioactive materials, hazardous wastes, flammable and combustible liquids and compressed gases.

General Considerations

When storing chemicals in the laboratory or stockroom they should be stored in appropriate cabinets and shelves as suggested in the following guidelines:

1. Chemicals should be stored in an uncluttered manner on shelves with solid backs and sides that are firmly secured.
2. Avoid storing chemicals in passageways, under tables, on bench tops , in hoods or stored as to block emergency equipment areas.
3. Volatile toxic substances and odoriferous chemicals should be stored in a ventilated cabinet.
4. Flammable liquids should be stored in an approved flammable liquid storage cabinet.
5. Chemical storage refrigerators are only to be used to store chemicals and should be labeled as such.
6. Refrigerators and microwaves intended for chemical use should be labeled with the following verbiage or equivalent:

NOT FOR FOOD OR DRINK

When storing chemicals the identity of the substance, any potential health and physical hazards, and any safe handling precautions should be known as suggested in the following guidelines:

1. Labels on all commercially packaged containers must not be defaced in accordance with the Laboratory Standard.
2. All purchased materials should be labeled with the date received.
3. All other containers used for storing chemicals should be labeled with the identity of the substance, the identity of any hazard components, appropriate hazard warnings, and the name, address, and telephone number of the manufacturer or responsible party.
4. For any chemical which is identified as being particularly hazardous, a flammable or combustible liquid, a compressed gas, or highly reactive the guidelines in the following sections must be consulted.

To minimize possible hazards associated with reactivity, chemicals should be separated into compatible groups and stored alphabetically within each group. Related and compatible storage groups are shown in **TABLE 1**

TABLE I . RELATED AND COMPATIBLE STORAGE GROUPS

INORGANIC FAMILY	ORGANIC FAMILY
metals, hydrides	acids, anhydrides, peracids
halides, sulfates, sulfites, thiosulfates, phosphates, halogens	alcohols, glycols, amines, imines, imides
amides, nitrates, (except ammonium nitrate), nitrites, azides	hydrocarbons, esters, aldehydes
hydroxides, oxides, silicates, carbonates, carbon	ethers, ketones, ketenes, halogenated hydrocarbons, ethylene oxide
Sulfides, selenides, phosphides, carbides, nitrides	epoxy compounds, isocyanates
chlorates, perchlorates, perchloric acid, chlorites, hypochlorites, peroxides, hydrogen peroxide	peroxides, hydroperoxides, azides
arsenates, cyanides, cyanates	sulfides, polysulfides, sulfoxides, nitrites
Borates, chromates, manganates, permanganates	
nitric acid, other inorganic acids	phenols, cresols
sulfur, phosphorous, arsenic, phosphorous pentoxide	

Storing Flammable and Combustible Liquids

There are limitations on both the container size for the storage of flammable and combustible liquids and the quantity of flammable and combustible liquids that can be stored in laboratories. Both NFPA Standards 30 and 45 and OSHA Standard 1910.106 limit the container size and the NFPA Standard 45 limits the quantity allowed in laboratories.

For storage purposes, flammable and combustible liquids are classified based on their flashpoints and boiling points. The following definitions from the Laboratory Standard apply :

flammable liquid

any liquid having a flashpoint below 100 F (37.8 C), except any mixture having components with flashpoints of 100 F or higher, the total of which make up 99 percent or more of the total volume of the mixture.

combustible liquid

a liquid having a flashpoint at or above 100 F(37.8 C) but below 200 F (93.3 C), except any mixture having components with flashpoints of 200 F or higher, the

total volume of which make up 99 percent or more of the total volume of the mixture.

flashpoint

the lowest temperature at which a liquid has a sufficient vapor pressure to form an ignitable mixture with air near the surface of the liquid.

Flammable liquids are known as Class I liquids and combustible liquids as Class II and III. Flammable and combustible liquids are further subdivided as follows:

- Class IA liquids include those having a flashpoint below 73 F and having a boiling point below 100 F.
- Class IB liquids include those having a flashpoint below 73 F and having a boiling point at or above 100 F.
- Class IC liquids include those having a flashpoint at or above 73 F and below 100 F.
- Class II includes liquids having flashpoints at or above 100 F but below 140 F.
- Class IIIA includes liquids having flashpoints at or above 140 F but below 200 F.

Class IIIB includes liquids having flashpoints at or above 200 F.

The following guidelines shall apply when storing flammable and combustible liquids in laboratories or laboratory units. A laboratory unit is defined as an enclosed space used for experiments or tests that may or may not include offices, laboratories, and other contiguous rooms maintained for use by laboratory personnel, and corridors within the unit. It may contain one or more separate laboratory work areas but it must be separated from other building areas by appropriate fire resistive construction having at least a one hour fire resistive rating.

1. The storage of flammable and combustible liquids in the open in the laboratory shall be kept to the minimum necessary for the work being conducted.
2. Containers of flammable and combustible liquids shall have appropriate identifying labels.
3. The maximum quantities of flammable and combustible liquids stored in research laboratories or general purpose laboratories shall not exceed the amounts given in **TABLE II** in accordance with NFPA Standard 45.

TABLE II. STORAGE LIMITS FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS*

Class of Liquid	Excluding Quantities in Storage Cabinets and Safety Cans		Including Quantities in Storage Cabinets and Safety Cans	
	Maximum Quantity per 100 sq. ft of Lab Unit (Gal)	Maximum Quantity per Lab Unit (Gal)	Maximum Quantity per 100 sq. ft of Lab Unit (Gal)	Maximum Quantity per Lab Unit (Gal)
Class I	2	75	4	150
Class II	4	100	8	200
Class IIIA	4	100	8	200

* In determining the quantity allowed, the more restrictive quantity based on either the lab unit or the quantity per 100 sq. ft of lab unit applies.

- The maximum quantities of flammable and combustible liquids in instructional laboratory units shall not exceed 50% of the quantities allowed in research laboratories in accordance with NFPA Standard 45.
- The maximum container size for the storage of flammable and combustible liquids in laboratories shall be in accordance with **TABLE III** as stated in NFPA standards 30 and 45 and OSHA Standard 1910.106.

TABLE III. ALLOWABLE CONTAINER SIZE FOR STORAGE OF FLAMMABLE AND COMBUSTIBLE LIQUIDS

	FLAMMABLE LIQUIDS (*)						COMBUSTIBLE LIQUIDS			
	Class IA		Class IB		Class IC		Class II		Class IIIA	
Container	L	Gal	L	Gal	L	Gal	L	Gal	L	Gal
Glass	0.5	0.12	1.0	0.25	4.0	1.0	4.0	1.0	4.0	1.0
Metal or Approved Plastic	4.0	1.0	20.0	5.0	20.0	5.0	20.0	5.0	20.0	5.0
Safety Cans	7.5	2.0	20.0	5.0	20.0	5.0	20.0	5.0	20.0	5.0

* Glass containers as large as 1 gallon (3.785L) are permitted when storing class IA liquids if needed and if the liquid is not compatible with metal or plastic containers and if the purity of the reagent would be adversely affected by storage in metal or plastic containers.

6. Flammable liquids are not to be stored in a refrigerator unless it is approved for flammable storage in accordance with NFPA Standards 45 and 56D. Refrigerators approved for flammable storage shall be labeled as such.

Storing Gas Cylinders

The Laboratory Standard defines a compressed gas as:

compressed gas

any material or mixture having in the container either an absolute pressure greater than 276 kPa (40 lbf/in²) at 21 C, or an absolute pressure greater than 717 kPa (104 lbf/in²) at 54 C, or both, or any liquid flammable material having a Reid vapor pressure greater than 276 kPa (40lbf/in²) at 38 C.

When storing compressed gas cylinders the following precautions should be observed:

1. The contents of every cylinder should be clearly identified with a durable label.
2. Compressed gas cylinders must be securely fastened at all times using a chain or clamp and belt.
3. Cylinders shall be stored so as not to be exposed to direct flame or heat in excess of 125 F.
4. Gas cylinder storage should be segregated from the storage of other chemicals and incompatible classes of gases should be further segregated.
5. Empty cylinders should be segregated from full cylinders.

In addition when storing flammable, toxic or corrosive gases the following guidelines must be adhered to:

1. Cylinders of flammable gases and cylinders of toxic or corrosive gases must be stored and used in a ventilated area as required by the NFPA Standard 45.
2. Cylinders of all gases having a Health Hazard Rating of 3 or 4 and those having a Health Hazard Rating of 2 with no physiological warning properties must be stored and used in a continuously mechanically ventilated hood or enclosure. No more than three gas cylinders with Health Hazard Ratings of 3 or 4 may be kept in a ventilated hood or enclosure.
3. The quantity and size of flammable and hazardous gas cylinders in laboratory work areas shall comply with the **TABLE IV**

TABLE IV. MAXIMUM QUANTITIES FOR GAS CYLINDERS IN LABORATORIES

	Flammable Gases and/or Oxygen		Liquefied Flammable Gases		Gases with Health Hazard Ratings of 3 or 4
	Sprinklered	Nonsprinklered	Sprinklered	Nonsprinklered	
max. # per 500 sq.ft. or less	6	3	3	2	3
max.size(in.)	10x50	10x50	9x30	9x30	4x15
approx.water vol (ft ³)	2.0	2.0	0.6	0.6	0.1

Storing Cryogenic Liquids and Liquefied Gases

Cryogenic liquids are materials that have boiling points of less than -75C (-100 F) and include liquid nitrogen, helium, and argon along with slush mixtures of dry ice with isopropanol. Gases such as oxygen and hydrogen are often used in the liquid state. In storing cryogenic liquids and liquefied gases:

1. Use containers that are designed for the pressures and temperatures to which they are subjected.
2. Dewar flasks used for small amounts of material should have a dust cap over the outlet to prevent moisture from condensing.

Storing Highly Reactive Substances

Highly reactive materials include peroxidizable substances, pyrophoric compounds, oxidizing agents, reducing agents, water reactive substances, thermally unstable compounds, and perchloric acid. The following precautions should be taken when storing these materials:

1. All highly reactive substances should be labeled, dated and inventoried when received. The label should state **DANGER! HIGHLY REACTIVE MATERIAL**
2. Containers of highly reactive materials should not be opened past the expiration date.
3. Highly reactive materials should be disposed of prior to the expiration date.

4. Highly reactive liquids should be stored in trays large enough to hold the contents of the container.
5. Materials that are highly reactive with water should be stored away from possible contact with water.
6. Thermally unstable chemicals should be stored in a chemical storage refrigerator.
7. Oxidizing agents should be segregated from reducing agents and combustibles.
8. Powerful reducing agents should be stored away from readily reducible substrates.
9. Pyrophoric compounds should be segregated from flammables.

Storing Peroxidizable Substances

Organic peroxides and peroxide forming materials are particularly dangerous in that the potential for an explosion occurring is very great. When storing organic peroxides and peroxide forming materials the following guidelines must be followed:

1. All containers of peroxidizable compounds should have a warning label indicating the date received and the date opened. The label should indicate that the material is to be tested or discarded within either 1, 3, or 6 months after opening as suggested in **TABLE V**.

TABLE V. PEROXIDE FORMING SUBSTANCES	
peroxide hazard on storage with exposure to air	
<i>Discard within 3 months</i>	
diisopropyl ether (isopropyl ether)	potassium amide
divinylacetylene	sodium amide
potassium metal	vinylidene chloride (1,1 -dichloroethylene)
peroxide hazard on Concentration	
<i>Discard or test for peroxides after 6 months</i>	
acetaldehyde diethyl acetal (acetal)	ethylene glycol dimethyl ether (glyme)
cumene (isopropyl benzene)	ethylene glycol ether acetates
cyclohexene	ethylene glycol monoethers
cyclopentene	furan
Decalin (decahydronaphthalene)	methylacetylene
diacetylene (butadiene)	methylcyclopentane
dicylopentadiene	methyl isobutyl ketone
diethyl ether	tetrahydrofuran
diethylene glycol dimethyl ether (diglyme)	tetralin (tetrahydronaphthalene)
dioxane	vinyl ethers
rapid polymerization hazard	

<i>Discard or test for peroxides after 6 months</i>	<i>Discard after 12 months</i>
chloroprene (2-chloro-1,3-butadiene)	butadiene
styrene	tetrafluoroethylene
vinyl acetate	vinylacetylene
vinyl pyridine	

2. All peroxidizable substances should be stored away from heat and light and be protected from ignition sources.
3. When it is necessary to test for the presence of peroxides:
 - o do not test the solution if it has been stored longer than two years.
 - o do not test the solution if crystals are visible in the container or crystals are on or in the container
 - o do not test the solution if the container has a metal screw cap.
 - o if it is safe to test the solution, the presence of peroxides can be detected by mixing 1-3 ml of the liquid to be tested with an equal volume of acetic acid and then adding a few drops of a 5% potassium iodide solution. A yellow to brown color indicates the presence of peroxides. Commercial test strips are also available.

If peroxides are present in solution they should be disposed of according to the appropriate hazardous waste management guidelines.

Storing Perchloric Acid

Perchloric acid is a powerful oxidizing agent. It can react explosively with organic compounds and reducing agents. In storing perchloric acid:

1. The quantity of perchloric acid in the laboratory should be limited to a one pound reagent bottle per specially designed perchloric acid hood constructed of stainless steel and provided with a water scrubber and stack washing ring.
2. Perchloric acid bottles should be kept in glass or ceramic trays.
3. Reagents bottles of perchloric acid not in current use should be segregated in a non-combustible cabinet.

Storing Particularly Hazardous Substances

Storing particularly hazardous substances such as carcinogens, reproductive toxins, and highly acute toxins should be in accordance with the following guidelines:

1. Particularly hazardous substances should be stored in a ventilated area.
2. Chemically resistant secondary containers should be used

3. Storage areas must be labeled with the appropriate warning signs such as:
CAUTION! REPRODUCTIVE TOXIN STORAGE
CAUTION! CANCER-SUSPECT AGENT STORAGE
CAUTION! HIGHLY TOXIC STORAGE
-

ENGINEERING CONTROLS

Engineering controls include fume hoods and other types of local ventilation devices such as glove boxes, storage cabinets, canopy hoods and gas cabinets. The use of engineering controls is extremely effective in minimizing exposures to hazardous materials.

FUME HOODS

The fume hood is probably the primary engineering control used to protect workers from exposure to hazardous materials in the laboratory. A fume hood is an enclosure with a movable sash that has been designed to prevent or minimize the escape of air contaminants into the laboratory. Air is drawn in from the laboratory but the fume hood is not designed to capture air contaminants generated outside of the enclosure, only those generated within. The fume hood is constructed of material that will withstand fire for several minutes but not necessarily explosions.

To be effective in controlling exposures to hazardous chemicals the laboratory fume hood must be operating properly and used correctly. To ensure proper operation of fume hoods:

1. Fume hoods shall be inspected quarterly by a qualified person designated by the CHO, who shall also keep a record of inspection results.
2. If a hood does not pass inspection and is unsafe for use it is labeled with a "**DO NOT USE**" sign . Appropriate personnel will then determine the cause of the problem and correct the faulty conditions.
3. During maintenance of fume hoods, the fume hood must be cleaned out and if necessary decontaminated. The use of chemicals in the fume hood is also restricted.
4. Modifications to hoods or duct work may not be made without consulting the Division Chair.
5. The user must monitor fume hoods daily to ensure that air is moving into the hood and to ensure that the hood and baffles are not blocked by equipment and bottles which may result in a decrease in the air velocity through the face. Monitoring may be done using a continuous reading device such as a pressure gauge or at a minimum a strip of tissue or yarn taped to the bottom of the vertical sliding sash. Any problems should be brought to the attention of the CHO.

The following guidelines are intended to ensure correct use of laboratory fume hoods:

1. A laboratory fume hood should be used when working with all hazardous substances.
2. A fume hood or other suitable containment device must be used:

- for all work involving " particularly hazardous substances ".
 - whenever the airborne concentration of a chemical is likely to approach the action level or PEL
 - whenever flammable vapors are likely to approach one tenth of the lower explosion limit
 - whenever noxious odors are given off
 - All highly toxic or offensive vapors should be scrubbed or absorbed before the exit gases are released into the hood exhaust system.
3. Chemicals and laboratory apparatus should be placed at least six inches behind the face of the hood.
 4. Large pieces of equipment should not be used in a fume hood.
 5. Fume hoods should not be used to store chemicals, apparatus or hazardous wastes. Only materials currently being used should be in the hood.
 6. The fume hood sash should be in the lowest possible position.

GLOVE BOXES

Glove boxes, which are usually small units with multiple openings to which arm length rubber gloves are mounted, are often used as containment devices. Glove boxes generally operate under negative pressure even though those used for experiments in which protection from the atmosphere is desired operate under positive pressure.

If toxic chemicals are used in a glove box, the box should be operated under negative pressure. The gloves should always be checked for the appropriate composition before use. The exhaust air may require special treatment (such as chemical scrubbing and/or HEPA (high efficiency particulate air) filtration) before release into the regular exhaust system.

If highly toxic materials must be used in a positive pressure glove box, the box and gloves must be tested for leaks prior to each use. It is also desirable to have a shut off valve or pressure gauge designed into the system for monitoring purposes.

PERSONAL PROTECTIVE AND OTHER SAFETY EQUIPMENT

Personal protective equipment, PPE, consists of eye protection, gloves, and apparel such as lab coats and aprons. While engineering controls are the most effective in reducing exposure to hazardous substances, the use of PPE will also minimize the risk of exposure to hazardous materials and should always be used in conjunction with engineering controls.

The MSDS for a given material describes what personal protective equipment should be used for its safe handling and use.

EYE PROTECTION

Contact with the eyes is one of the primary routes of exposure to hazardous substances. Therefore, eye protection is necessary for all work involving the use and handling of chemicals no matter how innocuous the material may seem.

All personnel and visitors must wear eye protection at all times while in Divisional laboratories where hazardous material are present in accordance with 29 CFR 1910.133. Eye protection is required whether or not one is actually performing a chemical operation. Visitors should not be permitted to enter a lab unless they are wearing appropriate eye protection. In areas where chemicals are handled, a supply of safety glasses should be available for the use of visitors and facilities management personnel. Also, signs indicating that eye protection is required must be posted.

Safety glasses with side shields meeting the American National Standards Institute Standard Z87.1-1989 provide the minimum acceptable eye protection for regular use. Ordinary prescription glasses do not provide adequate protection against eye injury and should not be used as safety glasses.

Contact lenses should not be worn in the laboratory. They offer no protection against eye injury and may interfere with first aid procedures including eye - flushing. If contact lenses must be worn for medical reasons, then tight fitting goggles should always be worn over the contact lenses.

When the possibility of splashing or spraying chemicals exists, or when there is a danger of flying particles goggles having splash proof sides should be worn. Goggles should be worn when working with hazardous substances, when working with glassware under reduced or elevated pressures, and when using glass apparatus in high temperature operations. In addition, full-face shields with throat protection should be used when working with highly hazardous or explosive materials.

For procedures involving exposure to laser, ultraviolet light, infrared light or intense visible light specialized eye protection should be worn.

GLOVES

Contact with skin is one of the major routes of exposure to hazardous substances. Therefore, gloves should be worn when working with chemicals. The Chemical Hygiene Plan requires that gloves be worn when working with particularly hazardous substances. Also, gloves are required when working with any substance on the OSHA list of regulated substances carrying a "skin" notation .

Gloves selected should be resistant to the chemical in use. The glove material should have the appropriate degradation and permeation characteristics to provide protection from the hazardous substance in use. Most manufactures provide glove selection guides, which contain further information on the chemical resistance to various classes of gloves. **TABLE VI** summarizes the chemical resistance to common glove materials.

Chemical	Natural Rubber	Neoprene	Nitrile	Vinyl
acetaldehyde	good	good	excellent	good
acetic acid	excellent	excellent	excellent	excellent
acetone	good	good	good	fair
acrylonitrile	poor	good		fair
ammonium hydroxide	good	excellent	excellent	excellent
Aniline	fair	good	excellent	good
benzaldehyde	fair	fair	excellent	good
Benzyl chloride	fair	poor	good	poor
bromine	good	good		good
Butane	poor	excellent		poor
butyraldehyde	poor	good		good
Calcium hypochlorite	poor	good	good	good
Carbon disulfide	poor	poor	good	fair
chlorine	good	good		good
chloroacetone	fair	excellent		poor
chloroform	poor	fair	good	poor
chromic acid	poor	fair	fair	excellent
cyclohexane	fair	excellent		poor

dibenzyl ether	fair	good		poor
dibutyl phthalate	fair	good		poor
diethanolamine	fair	excellent		excellent
Diethyl ether	fair	good	excellent	poor
ethyl acetate	fair	good	good	fair
ethylene dichloride	poor	fair	good	poor
ethylene glycol	good	good	excellent	excellent
ethylene trichloride	poor	poor		poor
fluorine	good	good		good
formaldehyde	good	excellent	excellent	excellent
formic acid	good	excellent	excellent	excellent
glycerol	good	good	excellent	excellent
Hexane	poor	excellent		poor
hydrobromic acid	good	excellent		excellent
hydrochloric acid	good	good	good	excellent
hydrofluoric acid	good	good	good	excellent
hydrogen peroxide	good	good	good	excellent
Iodine	good	good		good
methylamine	good	good	excellent	excellent
Methyl cellosolve	fair	excellent		poor
Methyl chloride	poor	excellent		poor
Methyl ethyl ketone	fair	good	good	poor
monoethanolamine	fair	excellent	good	excellent
morpholine	fair	excellent		excellent
naphthalene	good	good	excellent	good
nitric acid	poor	poor	poor	good
perchloric acid	fair	good	fair	excellent
Phenol	good	excellent		excellent
phosphoric acid	good	excellent		excellent
potassium hydroxide	good	good	good	excellent
propylene dichloride	poor	fair		poor
Sodium hydroxide	good	good	good	excellent
Sodium hypochlorite	good	poor	fair	good
Sulfuric acid	good	good	fair	good
Toluene	poor	fair	good	fair

trichloroethylene	poor	fair	good	fair
tricresyl phosphate	poor	fair		fair
triethanolamine	fair	excellent	excellent	excellent
trinitrotoluene	poor	excellent		poor

Always inspect gloves before use to ensure that they do not have any cracks or small holes in them. If gloves are torn they should be replaced immediately. Gloves should always be removed before leaving the work area and before handling objects such as telephones, doorknobs, notebooks and writing instruments. Before gloves are taken off, they should be appropriately decontaminated or washed. When gloves can no longer be reused they should be disposed of appropriately.

PROTECTIVE APPAREL

Protective apparel such as laboratory coats, aprons and gloves should be worn if the possibility of contaminating personal clothing with hazardous chemicals exists. The choice of apparel depends on the specific hazardous materials being used. Factors to consider in apparel choice include resistance to physical hazards, chemical and thermal resistance, ease and flexibility of movement, ease of removal and ease of cleaning or disposal. **TABLE VII** summarizes the properties of protective apparel materials.

MATERIAL	CHEMICAL RESISTANCE	FLAMMABILITY	STATIC PROPERTIES	USES
Cotton	degraded by acids, binds	special treatment for flame	no static problems	lab coats
Modacrylic	resistant to most chemicals	resists flame penetration in direct flame, will not melt or drip, self extinguishing, rapidly dissipates when ignition source is removed	antistatic properties	lab coats
Nylon	not water absorbent	melts when heated, requires flame retardant	static buildup, requires antistatic agent	lab coats
Plastic	resistant to corrosives	can be ignited by flammable solvents	accumulates static charge	aprons, sleeves, protectors,

				boots
Polypropylene	resistant to most chemicals, light sensitive	low melting point, requires flame retardant	static buildup, requires antistatic agent	aprons
Rayon	degraded by acids, binds some chemicals			lab coats

SAFETY SHOWERS AND EYEWASH FACILITIES

All work areas in which hazardous substances are in use must be equipped with both an easily accessible and properly functioning safety shower and an easily accessible and properly functioning eyewash facility. The safety shower and eyewash facility must meet the requirements of 29 CFR 1910.151(c).

Safety showers and eyewash stations shall have prominent signs as well as reveal monthly documentation of the weekly testing of showers and eyewash stations.

GENERAL SAFETY GUIDELINES

Before working in the laboratory one should familiarize him/herself with the following safety guidelines so that all individuals will be protected from the health and physical hazards associated with work in the laboratory.

1. Assess the health and physical hazards associated with the chemicals in use so that the appropriate safety measures can be taken to minimize any potential risks involved. The following guidelines are intended to help the worker evaluate and assess the hazards and risks.
 - identify the chemicals to be used.
 - identify the circumstances of use, for example the amounts to be used or the possibility of generating new or unknown substances.
 - consult sources of information on hazard identification.
 - evaluate the types of hazards associated with each chemical.
 - for any chemical, which is defined as hazardous, the standard operating procedure for working with that type of hazard must be followed in addition to the general safety guidelines.
 - be aware of all the safeguards for using the chemicals including when to implement control measures, personal protective equipment to be used, emergency responses, and handling of hazardous wastes.

2. Avoid underestimation of the risk involved in working with chemicals by
 - assuming that substances of unknown toxicity are hazardous.
 - assuming that a mixture will be more toxic than its most toxic component.

3. The laboratory worker should have knowledge of and be continually aware of:
 - the location and the proper use of emergency equipment such as eye wash stations, safety showers, fire extinguishers, and spill carts.
 - the location of telephones and emergency telephone numbers.
 - emergency responses including evacuation procedures and chemical spill cleanup procedures.
 - the procedures for handling chemical wastes.
 - how and where to store chemicals.
 - the proper methods of transporting chemicals.

4. Minimize exposure to chemicals by:
 - avoiding skin contact with chemicals.
 - avoiding inhalation of chemicals.
 - avoiding ingestion of chemicals.
 - wearing appropriate eye protection.

5. Eye protection must be worn by all individuals including visitors at all times while in Divisional laboratories where hazardous materials are present.

6. Skin contact and ingestion can be avoided by:
 - wearing appropriate gloves.
 - never tasting chemicals.
 - never using mouth suction to pipet chemicals.
 - not eating, drinking, smoking or applying cosmetics in laboratories or chemical storage areas.
 - always washing your hands with soap and water before leaving the laboratory or chemical storage area.
 - washing immediately when a chemical has contacted the skin.
 - wearing appropriate protective clothing.
 - confining long hair, not wearing loose clothing ,open-toed shoes, sandals, shoes made of woven material or shorts.

7. Inhalation of chemicals can be avoided by:
 - not smelling substances of unknown toxicity.
 - using a fume hood or other containment device when permissible exposure limits are likely to be exceed.
 - using a fume hood or other containment device when working with volatile hazardous substances.
 - using a fume hood or other containment device when working with substances of unknown toxicity.

8. Working alone in the laboratory should be avoided. When working alone, particularly with hazardous substances, arrangements should be made with other workers to check on you periodically.

9. No children or pets are allowed in Divisional laboratories.

10. If it is necessary to carry out laboratory operations continuously or if they are left overnight the laboratory worker should:
 - post signs identifying the hazardous substances in use and the nature of the operation.
 - make arrangements to have the operation checked periodically.
 - post information indicating how to be contacted in case of an emergency.
 - design the procedure with the appropriate safeguards to prevent the release of hazardous substances.
 - make sure that all water hoses are securely fastened as water pressure increases after hours.

11. The laboratory should be maintained in an orderly fashion by:
 - keeping all work areas clean.
 - keeping aisles, hallways and stairs clear of all chemicals.
 - not obstructing access to emergency equipment, safety showers, eye washes and exits.
 - promptly cleaning up chemical spills.
 - properly storing chemicals.
 - properly labeling and storing wastes.

STANDARD OPERATING PROCEDURES FOR WORKING WITH PHYSICAL HAZARDS

In this section of the manual are the standard operating procedures for working with chemicals that are potential physical hazards. Standard operating procedures describe precautions and measures beyond general laboratory practices that the laboratory worker should follow to minimize the dangers associated with potential physical hazards. Before consulting the appropriate standard operating procedure, the general safety guidelines in of this safety manual should be read and understood. In addition, it is possible that a substance may be both a potential physical and health hazard. It is then necessary to consult the appropriate standard operating procedures for both physical and health hazards.

FLAMMABLES AND COMBUSTIBLES

Flammable and combustible substances are routinely used in most laboratories and are, therefore, a common source of fire hazard. Flammable substances will readily catch fire and burn in air and may be either solids, liquids or gases. The following definitions from the Laboratory Standard apply:

flammable liquid

any liquid having a flashpoint below 100 F (37.8 C), except any mixture having components with flashpoints of 100 F or higher, the total of which make up 99 percent or more of the total volume of the mixture.

flammable solid

a solid that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard.

flammable gas

a gas that, at ambient temperature and pressure forms a flammable mixture with air at a concentration of 13 percent by volume or less or forms a range of flammable mixtures with air regardless of the lower limit.

combustible liquid

a liquid having a flashpoint at or above 100 F(37.8 C) but below 200 F (93.3 C), except any mixture having components with flashpoints of 200 F or higher, the

total volume of which make up 99 percent or more of the total volume of the mixture.

flashpoint

the lowest temperature at which a liquid has a sufficient vapor pressure to form an ignitable mixture with air near the surface of the liquid.

ignition temperature

the minimum temperature required to initiate or cause self-sustained combustion independent of the heat source.

limits of flammability

the range of concentrations in mixtures of air that will propagate a flame and cause an explosion.

Flammable gases pose special hazards since leakage or escape of the gas can produce an explosive atmosphere in the laboratory. Especially hazardous are acetylene, ammonia, hydrogen sulfide, propane, carbon monoxide, and hydrogen.

A knowledge of the flammability characteristics of a substance is essential for the proper handling of flammable materials. Flashpoints, limits of flammability, and ignition temperatures are characteristics that are readily available for most common laboratory chemicals. **Table VIII** summarizes flammability characteristics for some common chemicals. Laboratory Chemical Safety Summaries also contain information on flammability characteristics. The flammability characteristics found in Table VIII and on LCSS's are based on standard test methods which may be different than conditions in the laboratory. Therefore, large safety factors should be applied when working with flammable and combustible materials. Many common solvents have flashpoints that are lower than room temperature making them potentially dangerous.

TABLE VIII. FLAMMABILITY CHARACTERISTICS OF COMMON CHEMICALS

	NFPA RATING	FLASH	BOILING	IGNITION	FLAMMABILITY	
		POINT (C)	POINT (C)	TEMP. (C)	LIMITS percent by volume	
					Lower	Upper
acetaldehyde	4	-37.8	21.1	175	4	60
acetic acid (glacial)	2	39	118	463	4	19.9

Acetone	3	-18	56.7	465	2.6	12.8
acetonitrile	3	6	82	524	3	16
carbon disulfide	3	-30	46.1	90	1.3	50
cyclohexane	3	-20	81.7	245	1.3	8
diethylamine	3	-23	57	312	1.8	10.1
Diethyl ether	4	-45	35	160	1.9	36
dimethyl sulfoxide	1	95	189	215	2.6	42
ethyl alcohol	3	12.8	78.3	365	3.3	19
heptane	3	-3.9	98.3	204	1.05	6.7
hexane	3	-21.7	68.9	225	1.1	7.5
hydrogen	4	-	-252	500	4	75
isopropyl alcohol	3	11.7	82.8	398	2	12
methyl alcohol	3	11.1	64.9	385	6.7	36
methyl ethyl ketone	3	-6.1	80	515	1.8	10
pentane	4	-40	36.1	260	1.5	7.8
styrene	3	32.2	146.1	490	1.1	6.1
tetrahydro-furan	3	-14	66	321	2	11.8
toluene	3	4.4	110.6	480	1.2	7.1
p-xylene	3	27.2	138.3	530	1.1	7

Probably the quickest way to assess the risk associated with flammable substances is to use the NFPA fire hazard ratings. These ratings are based on the severity of the fire hazard and the following criteria apply:

- 0 substance will not burn
- 1 substance must be preheated to burn
- 2 substance ignites when moderately heated
- 3 substance ignites at normal temperatures
- 4 substance is extremely flammable

The following guidelines should be followed when working with flammable and combustible substances:

1. Know the flammability properties of the chemicals being used. Pay particular attention to substances with NFPA fire hazard ratings of 3 or 4.
2. Containers of flammable and combustible liquids shall have appropriate identifying labels.
3. The amount of flammable material in the open in the laboratory shall be kept to the minimum necessary for the work being conducted.
4. When not in use, flammable substances must be stored properly.
5. Eliminate ignition sources from areas where flammable substances are handled. Ignitions sources include electrical equipment, open flames, static electricity, lighted matches, and hot surfaces.
6. Never use an open flame to heat flammable materials. Heat sources such as steam baths, water baths, oil baths, heating mantles or hot air baths are preferred.
7. When transferring flammable substances from one container to another, when allowing flammable substances to stand in open containers or when heating flammable substances in open containers the vapors should be diluted by ventilation. Be sure that the equipment used for ventilation is explosion proof.
8. When transferring flammable liquids in metal equipment static generated sparks should be avoided by grounding and the use of ground straps.
9. Before introducing flammable gases into a reaction vessel, the equipment should be purged either by evacuation or with an inert gas.

COMPRESSED GASES

Depending on the identity of the compressed gas, it can be both a potential physical and a potential health hazard. The compression of a gas results in a large amount of potential energy. Therefore, compressed gas cylinders are high energy sources and are potential explosives. Compressed gas cylinders can act as a rocket or fragmentation bomb. If the gas is flammable there is also the potential for a fire or explosion to occur.

Also, the reactivity and toxicity of the gas can result in associated health hazards. Even inert gases such as nitrogen can be hazardous since high concentrations can cause asphyxiation.

The Laboratory Standard defines a compressed gas as:

compressed gas

any material or mixture having in the container either an absolute pressure greater than 276 kPa (40 lbf/in²) at 21 C, or an absolute pressure greater than 717 kPa (104 lbf/in²) at 54 C, or both, or any liquid flammable material having a Reid vapor pressure greater than 276 kPa (40lbf/in²) at 38 C.

Before working with compressed gases, one should become familiar with the general guidelines for handling and using compressed gases in addition to any other physical or health hazards associated with the particular gas. The following precautions should be taken when storing, handling and using compressed gas cylinders:

1. The contents of every cylinder should be clearly identified with a durable label.
2. No cylinder of gas should be accepted that is not clearly identified.
3. Before handling a specific gas, the Material Data Safety Sheet, LCSS or other appropriate reference material should be consulted for specific hazards and safety precautions.
4. Gas lines leading from a compressed gas supply must be clearly labeled with the identity of the gas, the laboratory being served and relevant emergency telephone numbers.
5. Compressed gas cylinders must be securely fastened at all times using a chain or clamp and belt.
6. The cylinder valve should be accessible at all times.
7. Cylinder valves should be opened slowly.
8. When equipment is not operating or left unattended, the cylinder valve should never be left open.
9. All pressure regulators should be equipped with spring-loaded pressure relief valves.
10. Cylinders should never be emptied to a pressure below 172 kPa (25 psi).
11. Empty cylinders of gas should never be refilled, and the regulator should be removed and replaced with the valve cap.
12. Except for lecture bottles, cylinders not in use should have The valve protective cap in place.

When working with compressed gases that are flammable, corrosive, irritating or toxic, the following additional guidelines should be observed:

1. When opening valves on irritating or toxic gases, it should be done in a fume hood or specially designed cylinder cabinet.
2. The relief valve on cylinders of hazardous gases should vented to a hood or other safe location.
3. Any hood dedicated for use with toxic gases should have a differential pressure switch and warning alarm.
4. Cylinders of flammable gases and cylinders of toxic or corrosive gases must be stored and used in a ventilated area as required by the NFPA Standard 45.
5. Cylinders of all gases having a Health Hazard Rating of 3 or 4 and those having a Health Hazard Rating of 2 with no physiological warning properties must be stored and used in a continuously mechanically ventilated hood or enclosure. No more than three gas cylinders with Health Hazard Ratings of 3 or 4 may be kept in a ventilated hood or enclosure.

CRYOGENS AND LIQUIFIED GASES

Cryogenic liquids have boiling points of less than -73 C (-100 F). Commonly used cryogenic liquids include liquid nitrogen, helium and argon and slush mixtures of dry ice with isopropanol. All of these substances are commonly used in cold traps. Other materials such as oxygen and hydrogen are, also, often used in the liquid state. The extreme cold of cryogenic liquids necessitates special care in their use. The main hazards associated with using cryogenic liquids are fire or explosion , pressure buildup, embrittlement of structural materials, frostbite, and asphyxiation.

The following guidelines are intended to minimize the hazards associated with working with cryogens and liquefied gases:

1. Eye protection, preferably a face shield, must always be worn when handling liquefied gases and cryogenic liquids.
2. Skin contact with cryogenic liquids should be avoided. Wear gloves that are impervious to the material being handled. Avoid being in contact with uninsulated vessels or pipes containing cryogenic liquids.
3. Objects in contact with cryogens should be handled with tongs or potholders.
4. Work involving cryogens should be conducted in a well ventilated area.
5. Use containers that are designed for the pressures and temperatures to which they are subjected.
6. Dewar flasks used for small amounts of material should have a dust cap over the outlet to prevent moisture from condensing and plugging the neck of the tube.
7. All equipment and cylinders containing flammable or toxic liquefied gases should have a spring-loaded pressure relief device.
8. Liquid hydrogen should not be transferred in an air atmosphere.
9. Liquid oxygen should be kept away from organic materials.
10. Liquid nitrogen should not be kept in a closed room.

OXIDIZERS

The Laboratory Standard defines an oxidizer as:

oxidizer

a chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.

Oxidizing agents tend to be corrosive, and are potential fire and explosive hazards. They may react violently when in contact with reducing materials. Sometimes they also undergo a violent reaction with ordinary combustibles and trace metals.

To minimize the hazards associated with working with oxidizers:

1. Know the reactivity of the materials being used in the process.
2. If the reaction is potentially violent or explosive use a safety shield.
3. Use the minimum amount of material necessary for the procedure.
4. Segregate oxidizers from flammable or combustible materials and reducing agents.
5. Liquid oxidizers should be stored in a secondary container that is large enough to hold the contents of the reagent container.
6. Oxidizers should be labeled, dated and inventoried when received. The label should state: **DANGER! OXIDIZING AGENT HIGHLY REACTIVE**

PYROPHORICS

Pyrophorics are substances that ignite spontaneously in contact with air. Examples of pyrophorics include many finely divided metals, metal hydrides, alloys of reactive metals, low-valent metal salts and iron sulfides. **Table IX** lists several specific examples of pyrophoric substances.

Class of compound	Examples
metal alkyls and aryls	RLi, RNa, RAl, RZn
metal carbonyls	Ni(CO) ₄ , Fe(CO) ₅ , Co ₂ (CO) ₈
alkali metals	Na, K
metal powders	Al, Co, Fe, Mg, Mn, Pd, Pt, Ti, Sn, Zn, Zr
metal hydrides	NaH, LiAlH ₄
nonmetal hydrides	B ₂ H ₆ , PH ₃ , AsH ₃
nonmetal alkyls	R ₃ B, R ₃ P, R ₃ As
phosphorous (white)	

When working with pyrophorics:

1. Avoid contact with air or water.
2. Work in inert environments.
3. Store pyrophorics in inert environments and away from flammables.
4. Pyrophorics should be labeled, dated and inventoried when received. The label should state: **DANGER! PYROPHORIC MATERIAL HIGHLY REACTIVE**

WATER REACTIVES

Substances that are classified as water reactive are those that react violently with water. Typically these materials result in a large evolution of heat when in contact with water, decompose in moist air and may violently decompose in liquid water. Water reactives include alkali metals, many organometallics, some hydrides, some anhydrous metal hydrides, nonmetal oxides and halides. **Table X** gives specific examples of water reactive substances.

Class of compound	Examples
alkali metals	Li, Na, K
anhydrous metal halides	AlCl ₃ , AlBr ₃ , TiCl ₄ , ZrCl ₄ , SnCl ₄
nonmetal halides	BCl ₃ , BF ₃ , PCl ₃ , PCl ₅ , SiCl ₄
nonmetal oxides	SO ₃ , PO ₅
inorganic acid halides	POCl ₂ , SOCl ₂ , SO ₂ Cl ₂
metal oxides	CaO

When working with water reactive substances:

1. Keep away from moisture.
2. Work in a fume hood.
3. Wear protective acid resistant rubber or plastic clothing along with gloves and a face shield.
4. Store materials that are highly reactive with water away from possible contact with moisture.
5. Water reactive materials should be labeled, dated and inventoried when received.
The label should state: **DANGER! WATER REACTIVE MATERIAL
HIGHLY REACTIVE**

INCOMPATIBLE CHEMICALS

Working with incompatible chemicals may result in the formation of substances that are toxic, flammable, explosive or have a combination of both physical and health hazards associated with them. **Table XI** lists some classes of incompatible chemicals (reactive hazards).

Class of Compound	Incompatible Classes of Compounds
alkali and alkaline earth carbides, hydrides, hydroxides, metals, oxides and peroxides	water, acids, halogenated organics, halogenating agents, oxidizing agents

inorganic azides	acids, heavy metals, salts of heavy metals, oxidizing agents
inorganic cyanides	acids, strong bases
inorganic nitrates	acids, reducing agents
inorganic nitrites	acids, oxidizing agents
inorganic sulfides	acids
organic anhydrides	bases, organic hydroxy and amino compounds
organic halogen compounds	group IA and IIA metals, aluminum
organic nitro compounds	strong bases
oxidizing agents	reducing agents

To minimize the risks involved in working with incompatible chemicals:

1. Know the hazards associated with incompatible substances used in the procedure.
2. Store incompatible chemicals properly as suggested in **Table I**.
3. Use the minimum quantities necessary in the process.
4. If in the procedure there is the potential for an explosion to occur, or it is likely that a flammable or toxic substance will be produced consult the appropriate section of the safety manual.

EXPLOSIVES

Special precautions must be taken in handling explosive materials. Explosions result when a substance undergoes a rapid reaction resulting in a violent release of energy. Explosive materials are those substances that either detonate or deflagrate. Many factors including heat, light, mechanical shock, and certain catalysts may initiate explosive reactions. Gases and fumes resulting from explosions may also have health hazards associated with them.

Table XII contains examples of typical classes of explosive compounds.

acetylenic compounds	alkyl or acyl peroxides
metal acetylides or carbides	alkyl hydroperoxides
haloacetylides	dialkyl peroxy carbonates
diazo compounds	metal fulminates, oximates
nitroso compounds	organic azides, acyl azides, metal azides, metal azide complexes
nitroalkanes, C-nitro and polynitroaryl compounds, polynitroalkyl compounds, trinitroethyl compounds	transition metal carbonyl compounds
acyl or alkyl nitrates	metal cyanides, organic nitriles, cyanogen halides
acyl or alkyl nitrites	

If it is necessary to work with explosive or highly reactive materials, the following guidelines must be adhered to:

1. Before working with explosive or potentially explosive substances, the hazards associated with the substances and any specific safety precautions must be known.
2. The experiment or process involving the materials must be discussed with a laboratory supervisor.
3. Use the minimum amounts necessary for the procedure.
4. Explosive chemicals should be brought into the laboratory only as required.
5. Potentially explosive substances should be labeled, dated and inventoried when received. The label should state: **DANGER! EXPLOSIVE MATERIAL**
6. All potentially explosive liquids should be stored in secondary containment trays large enough to hold the contents of the container.

PERCHLORIC ACID AND PERCHLORATES

A particularly powerful oxidizing agent is perchloric acid. Perchloric acid has the potential for undergoing explosive reactions with organic compounds and reducing agents. Besides perchloric acid, perchlorate esters and transition metal perchlorates are capable of exploding.

The following precautions should be observed when working with perchloric acid:

1. Perchloric acid should only be used in a water wash down perchloric acid fume hood.
2. Perchloric acid should not be used near wooden tables or benches.
3. When adding perchloric acid to organic material, the organic matter should first be digested with nitric acid.
4. Do not heat perchloric acid with sulfuric acid. Heating with sulfuric acid may produce anhydrous perchloric acid which is explosive.
5. Store perchloric acid properly.

ORGANIC PEROXIDES AND PEROXIDE FORMING SUBSTANCES

Organic peroxides are one of the more hazardous classes of chemicals commonly found in the laboratory. Generally they are low power explosives, but they are extremely sensitive to shock, sparks, and other forms of accidental ignition. In addition, organic peroxides are highly flammable. There are also many potentially hazardous compounds that autooxidize when exposed to air and form hydroperoxides and peroxides. **Table V** lists examples of compounds which are known to form peroxides.

Precautions for handling peroxides include:

1. Use the minimum quantity required.
2. Do not return unused peroxides to the container.
3. All spills involving peroxides should be cleaned up immediately. Solutions of peroxides can be absorbed on vermiculite or other absorbing material.
4. Inert solvents can be used to dilute peroxides which reduces their sensitivity to shock and heat. Do not use aromatic solvents.
5. Metal spatulas should not be used when handling peroxides.
6. Sources of heat are not allowed near peroxides.
7. Avoid forms of impact near peroxides.
8. Store peroxides and peroxide forming materials properly.

STANDARD OPERATING PROCEDURES FOR WORKING WITH HEALTH HAZARDS

Prior to using substances classified as health hazards, it is essential that the risks associated with these chemicals be well understood. All substances can potentially have adverse effects on living systems depending on the duration of exposure, frequency of exposure and the inherent toxicity of the particular substance. Toxic effects can be acute, causing damage after a single short duration exposure or chronic, causing damage either after repeated or long duration exposure or a long latency period. Some chemicals may have both acute and chronic toxic effects.

Permissible exposure limits have been established by OSHA (29 CFR 1910.1000) to protect workers from overexposure to airborne concentrations of hazardous substances. The Laboratory Standard requires that:

- the PEL for regulated substances not be exceeded
- for substances that have action levels, requirements for medical and exposure monitoring become effective
- for 'select carcinogens', reproductive toxins, and substances with a high degree of acute toxicity, additional protective measures beyond general laboratory practice must be considered

Therefore, standard operating procedures must be practiced when working with any chemical classified as a health hazard as required by the Laboratory Standard. It is highly possible that a specific chemical may exhibit several adverse health effects and it is then necessary to consult all appropriate procedures. It is the responsibility of the laboratory supervisor to ensure that the PEL for a specific chemical not be exceeded.

In this section of the manual are standard operating procedures for working with irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents acting on the hematopoietic system and agents which damage the lungs, skin, eyes, or mucous membranes. Carcinogens, reproductive toxins and substances that have a high degree of acute toxicity are considered to be particularly hazardous and standard operating procedures for working with these materials are found in the next section of this safety manual. The standard operating procedures describe precautions in addition to general safety guidelines which the laboratory worker must take to be protected from exposure to health hazards. Also included are examples of the particular class of hazardous chemical. However, these lists are not exhaustive and it is advisable to always consult the MSDS, LCSS or other appropriate reference material for a specific compound.

CORROSIVES

As defined in 29 CFR 1910.1250, a corrosive is:

corrosive

a chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact.

Corrosive materials are commonly found in the laboratory and can effect the skin and eyes, the respiratory tract and if ingestion occurs, the gastrointestinal tract.

Corrosive substances exist as solids, liquids and gases. Liquids such as bromine, sulfuric acid, sodium hydroxide solutions and hydrogen peroxide, tend to be especially dangerous since their action on skin occurs very rapidly. Corrosive gases can cause serious lung damage. Typical examples of corrosive gases include chlorine, ammonia and nitrogen dioxide. Solids such as sodium hydroxide, phosphorous and phenol can be corrosive to the skin and dusts from corrosive solids can also seriously damage the respiratory tract.

There are many classes of compounds that exhibit corrosive properties. Strong acids, strong bases, strong dehydrating agents, and strong oxidizing agents tend to be corrosive. **Table XIII** gives several specific examples of corrosive materials.

acetic acid	cupric bromide	potassium cyanide
aluminum chloride	hydrochloric acid	potassium fluoride
ammonium dichromate	hydrofluoric acid	potassium metal
ammonium oxalate	hydroquinone	sodium cyanide
antimony pentachloride	lithium	sodium ferrocyanide
antimony trichloride	nitric acid	sodium hydroxide
bismuth trichloride	oxalic acid	disodium hexafluorosilicate
bromine	phosphorous (white)	stannic chloride
calcium oxide	phosphorous pentoxide	sulfuric acid
chlorine	potassium chromate	

Precautions for working with corrosives include:

Minimize skin and eye contact by wearing eye protection and rubber gloves that are resistant to the corrosive. If appropriate also use a face shield and protective apparel.

1. Minimize inhalation of corrosives by working in a fume hood or other containment device when handling volatile corrosives.
2. In areas where corrosives are used and stored, an eyewash and safety shower must be readily available. In the event of skin or eye contact, the area of contact should be flushed with cool water for 15 minutes.
3. All containers and equipment used for storage and handling of corrosives should be corrosion resistant.
4. Incompatible classes of corrosives should be segregated.

IRRITANTS

According to 29 CFR 1910.1250 an irritant is defined as:

irritant

a chemical which is not corrosive, but which causes a reversible inflammatory effect on living tissue by chemical action at the site of contact.

There are a large number of chemicals, both organic and inorganic, that are irritants. Several examples are shown in **Table XIV**.

acetaldehyde	p-dichlorobenzene	methyl methacrylate
acetic anhydride	diethyl phthalate	methyl salicylate
ammonia	ethyl methacrylate	naphthalene
antimony oxide	ferric chloride	phthalic anhydride
calcium carbide	Hexachlorophene	potassium permanganate
calcium fluoride	hydrogen peroxide	sodium sulfide
catechol	hydrogen sulfide	sulfuric acid, fuming
cupric chloride	iodine (crystals)	titanium trichloride
cupric nitrate	lead carbonate	toluene
cupric sulfate	methyl ethyl ketone	trichlorotrifluoroethane

Precautions for working with irritants include:

1. Minimize skin and eye contact by wearing eye protection and rubber gloves. If appropriate also use a face shield and protective apparel.
2. Minimize inhalation of irritants by working in a fume hood or other containment device when handling volatile irritants.
3. An eyewash and safety shower must be readily available.

SENSITIZERS

As defined in 29 CFR 1910.1250, a sensitizer is:

sensitizer

a chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical.

An allergic reaction to a chemical results from previous sensitization to the chemical or to a structurally similar one. The reaction can be immediate or delayed and after sensitization occurs can result from exposure to extremely small doses of the substance.

The tendency to become sensitized to a chemical differs widely among individuals. It is possible that an individual will exhibit an allergic response even if the recommended personal protective measures are taken. Individuals working with sensitizers should be aware of the signs and symptoms associated with allergic responses to chemicals, which include red, swollen, and itchy skin and eyes. Anaphylactic shock is an example of a severe immediate allergic reaction. It is advisable to consult the MSDS for the specific sensitizer. Examples can be found in **Table XV**.

nickel and nickel salts	thiuram sulfides	hexamethylenediisocyanate
chromium salts	p-phenylenediamine	p-tertiary butyl phenol
cobalt salts	Diphenylguanidine	formaldehyde
organomercurials	resorcinol monobenzoate	neomycin
mercaptobenzthiazole	methyl methacrylate	benzocaine

When work involves sensitizers:

1. Consult the MSDS or LCSS for the specific sensitizer.
2. Be aware of signs and symptoms associated with allergic responses to the sensitizer.
3. Be aware of emergency responses to allergic reactions to the sensitizer.
4. Avoid skin and eye contact by wearing eye protection and gloves. If appropriate also wear other protective apparel.
5. Avoid inhalation by working in a fume hood or other containment device.

TOXINS AFFECTING TARGET ORGANS

Toxic substances found in the laboratory may have adverse effects on many different target organs including the nervous system, the blood system, lungs, skin, eyes, the liver, and kidneys in addition to the reproductive system. **Table XVI** categorizes the effects of toxins on target organs and includes signs and symptoms of exposure and examples of the different types of toxins.

TABLE XVI. TOXINS AFFECTING TARGET ORGANS			
Type of Toxin	Affected Organ	Signs and Symptoms	Examples
hepatotoxins	liver	jaundice, liver enlargement	carbon tetrachloride, nitrosamines
nephrotoxins	kidney	edema, proteinuria	halogenated hydrocarbons, uranium
neurotoxins	nervous system	narcosis, behavioral changes, decrease in motor functions	mercury, carbon disulfide
agents acting on the hematopoietic system	hemoglobin, deprive the body tissues of oxygen	cyanosis, loss of consciousness	carbon monoxide, cyanides
agents which damage the lung	pulmonary tissue	cough, tightness in chest, shortness of breath	silica, asbestos
cutaneous hazards	dermal layer of the body	defatting of the skin, rashes, irritation	ketones, chlorinated compounds
eye hazards	eye	conjunctivitis, corneal damage	organic solvents, acids

Precautions that should be taken when working with toxins affecting target organs include:

1. Consult the MSDS or LCSS for specific toxicological effects of the toxin.
 2. Be aware of signs and symptoms associated with exposure.
 3. Be aware of emergency responses.
 4. Avoid skin and eye contact by wearing eye protection, gloves and any other appropriate protective apparel.
 5. Avoid inhalation by working in a fume hood or other containment device.
-

STANDARD OPERATING PROCEDURES FOR WORKING WITH PARTICULARLY HAZARDOUS SUBSTANCES

According to the Laboratory Standard (29 CFR 1920.1450) certain classes of hazardous substances are considered to be particularly hazardous. Provisions for additional protection for personnel working with 'select carcinogens', reproductive toxins, and substances with a high degree of acute toxicity are required by the standard. Individuals working with particularly hazardous chemicals must consult the appropriate standard operating procedure in addition to all of the general safety guidelines. It is also advisable to consult the MSDS, LCSS or other appropriate reference material for the specific substance. The Laboratory Standard also requires that:

- the PEL for regulated substances not be exceeded
- for substances that have action levels, requirements for medical and exposure monitoring become effective
- for 'select carcinogens', reproductive toxins, and substances with a high degree of acute toxicity, additional protective measures beyond general laboratory practice must be considered

Therefore, standard operating procedures must be practiced when working with any chemical classified as a health hazard as required by the Laboratory Standard. It is highly possible that a specific chemical may exhibit several adverse health effects and it is then necessary to consult all appropriate procedures. It is the responsibility of the laboratory supervisor to ensure that the PEL for a specific chemical not be exceeded.

The standard operating procedures for working with particularly hazardous substances are presented in this section of the safety manual and include procedures for working with 'select carcinogens', reproductive toxins, and substances that have a high degree of acute toxicity. These procedures emphasize the use of containment devices, the establishment of designated areas, the removal of contaminated waste and decontamination procedures.

It is essential that all work with particularly hazardous substances be conducted in a designated area. A designated area is defined in 29 CFR 1910.1450 as:

designated area

an area which may be used for work with 'select carcinogens', reproductive toxins or substances which have a high degree of acute toxicity. A designated area may be the entire laboratory, an area of a laboratory or a device such as a hood.

A designated area must be posted with a highly visible sign.

SELECT CARCINOGENS

Carcinogens are substances that are capable of causing cancer and are chronically toxic agents. Those substances exhibiting the greatest carcinogenic hazard are referred to as 'select carcinogens' and according to the Laboratory Standard are considered to be particularly hazardous. A 'select carcinogen' is defined as:

select carcinogen

a substance that meets one of the following criteria:

1. It is regulated by OSHA as a carcinogen.
2. It is listed under the category "known to be carcinogens" in the Annual Report on Carcinogens published by the National Toxicology Program(NTP).
3. It is listed under group I ("carcinogenic to humans") by the International Agency for Research on Cancer Monographs(IARC)
4. It is listed in either Group 2A or 2B by IARC or under the category "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria: (a) after inhalation exposure of 6 to 7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m³ ; (b) after repeated skin application of less than 300 mg/kg of body weight per week; or (c) after oral doses of less than 50 mg/kg of body weight per day.

Table XVII lists general classes of compounds for which some members of the class have been identified as carcinogens.

TABLE XVII. EXAMPLES OF CLASSES OF CARCINOGENS			
Class of Substance	Examples	Class of Substance	Examples
alkylating agents	a - haloethers:	hydrazines	hydrazine
	bis(chloromethyl) ether		
	methyl chloromethyl ether		1,2-dimethylhydrazine
	sulfonates :		
	1,4-butanediol dimethanesulfonate		1,1-dimethylhydrazine
	diethylsulfate		1,2-dimethylhydrazine
	dimethyl sulfate	N-nitroso compounds	N-nitrosodimethylamine
	ethyl methanesulfonate		N-nitros-N-alkylureas
	methyl methanesulfonate	aromatic	4-aminobiphenyl

		amines	
	methyltrifluoromethanesulfonate		benzidine
	1,3- propanesulfonate		a - naphthylamine
	epoxides: ethylene oxide		b - naphthylamine
	diepoxybutane		aniline
	epichlorohydrin		<i>o</i> - anisidine
	propylene oxide		2,4-diaminotoluene
	styrene oxide		<i>o</i> - toluidine
	aziridines: ethylenimine	aromatic hydrocarbons	benzene
	2-methylaziridine		benz[<i>a</i>] anthracene
	diazo, azo and azoxy compounds: 4-dimethylaminoazobenzene		benzo[<i>a</i>]pyrene
	electrophilic alkenes and alkynes: acrylonitrile acrolein ethyl acrylate	natural products	aflatoxins bleomycin cisplatin progesterone
			reserpine
acylating agents	b - propiolactone		
	b - butyrolactone		
	dimethylcarbamyl chloride		
organohalogen compounds	1,2 -dibromo-3- chloropropane	miscellaneous organic compounds	formaldehyde
	bis(2-chloroethyl)sulfide		acetaldehyde
	vinyl chloride		1,4-dioxane
	carbon tetrachloride		ethyl carbamate
	chloroform		hexamethylphosphoramide

	3-chloro-2-methylpropene		2-nitropropane
	1,2- dibromoethane		styrene
	1,4-dichlorobenzene		thiourea
	1,2-dichloroethane		thioacetamide
	2,2-dichloroethane	miscellaneous inorganic compounds	arsenic and some arsenic compounds
	1,3-dichloropropene		chromium and some chromium compounds
	hexachlorobenzene		thorium dioxide
	methyl iodide		beryllium and some beryllium compounds
	tetrachloroethylene		cadmium and some cadmium compounds
	trichloroethylene		lead and some lead compounds
			nickel and some nickel compounds
	2,4,6-trichlorophenol		selenium sulfide

The general procedures for working with carcinogens are:

1. Consult the MSDS, LCSS or other appropriate sources of information for toxicological properties, special precautions, recommended protective equipment and apparel, waste handling procedures, decontamination procedures, and emergency responses.
2. All areas in the Division are required to maintain a list of particularly hazardous substances including 'select carcinogens'.
3. The laboratory worker must obtain permission from the laboratory supervisor prior to initiating any process involving carcinogens.
4. In all experiments involving carcinogens, the amounts of material used and the names of workers involved should be kept as part of the laboratory notebook.
5. All processes involving carcinogens in quantities greater than 10 mg must be done in a **DESIGNATED AREA** with a highly visible sign reading "**DESIGNATED AREA FOR USE OF CARCINOGENS- AUTHORIZED PERSONNEL ONLY**".
6. Carcinogens should be stored properly with a label such as **WARNING ! CANCER SUSPECT AGENT** in a designated area. Store volatile carcinogens in a secondary tray or container in a ventilated storage area (under a slightly negative pressure).

7. Avoid skin and eye contact by wearing eye protection, suitable gloves and laboratory coats or aprons and any other protective apparel suggested in the MSDS or LCSS.
8. Any carcinogens that can generate dust, vapors or aerosols must be handled in a suitable containment device, such as a fume hood or glove box, in a designated area.
9. Equipment used for carcinogens should be isolated from general laboratory equipment.
10. Vacuum pumps should be protected by high-efficiency scrubbers or HEPA filters and vented into an exhaust hood.
11. Hazardous wastes involving carcinogens must be disposed of in accordance with the procedures in the section on Hazardous Wastes and have an identifying label such as **CARCINOGEN**.
12. After work in an area designated for carcinogens is complete, the area must be decontaminated. All equipment including personal protective equipment must not be removed from the designated area without decontamination.

REPRODUCTIVE AND DEVELOPMENTAL TOXINS

Reproductive toxins are defined as:

reproductive toxins

chemicals which affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis).

Reproductive toxins can have adverse effects on both men and women. Many reproductive toxins are chronic toxins and therefore the effects may only become evident after repeated or long duration exposures. **Table XVIII** lists examples of reproductive toxins.

arsenic and certain arsenic compounds	ethylene oxide
benzene	lead compounds
cadmium and certain cadmium compounds	mercury compounds
carbon disulfide	toluene
ethylene glycol	vinyl chloride
	xylene

Developmental toxins cause adverse effects on the embryo or fetus during pregnancy.

When working with reproductive or developmental toxins:

1. Consult the MSDS, LCSS or other appropriate sources of information for toxicological properties, special precautions, recommended protective equipment and apparel, waste handling procedures, decontamination procedures, and emergency responses.
2. Women of childbearing age should be especially cautious when working with chemicals that are suspected reproductive toxins or developmental toxins.
3. All areas in the Division are required to maintain a list of particularly hazardous substances including reproductive and developmental toxins.
4. The laboratory worker must obtain permission from the laboratory supervisor prior to initiating any process involving reproductive and developmental toxins.
5. In all experiments involving reproductive and developmental toxins, the amounts of material used and the names of workers involved should be kept as part of the laboratory notebook.
6. All processes involving reproductive toxins in quantities greater than 10 mg must be done in a **DESIGNATED AREA** with a highly visible sign reading **"DESIGNATED AREA FOR USE OF REPRODUCTIVE TOXINS-AUTHORIZED PERSONNEL ONLY"**
7. Reproductive toxins should be stored properly with a label such as **WARNING REPRODUCTIVE TOXIN** in a designated area. If they are volatile they should be stored in a secondary tray or container in a ventilated storage area (under a slightly negative pressure).
8. Avoid skin and eye contact by wearing eye protection, suitable gloves and laboratory coats or aprons and any other protective apparel suggested in the MSDS or LCSS.
9. Any reproductive toxins that can generate dust, vapors or aerosols must be handled in a suitable containment device, such as a fume hood or glove box, in a designated area.
10. Equipment used for reproductive toxins should be isolated from general laboratory equipment.
11. Vacuum pumps should be protected by high-efficiency scrubbers or HEPA filters and vented into an exhaust hood.
12. Hazardous wastes involving reproductive toxins must be disposed of in accordance with the procedures in the section on Hazardous Wastes and have an identifying label such as **REPRODUCTIVE TOXIN**.

COMPOUNDS WITH A HIGH DEGREE OF ACUTE TOXICITY

Compounds with a high degree of acute toxicity are those that have a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each. Median lethal dose refers to the quantity of material required to produce a lethal response in 50 percent of the test animals. According to the Laboratory Standard, substances with a high degree of acute

toxicity are considered to be particularly hazardous. **Table XIX** gives several examples of highly acute toxic materials. Also **TABLE XX** lists the Category 1 Gaseous Poison

acrolein	nickel carbonyl
arsine	nitrogen dioxide
chlorine	osmium tetroxide
diazomethane	ozone
diborane	phosgene
hydrogen cyanide	sodium azide
hydrogen fluoride	sodium cyanide and other cyanide salts
methyl fluorosulfonate	

TABLE XX. POISON INHALATION HAZARDS: CLASS A POISONS

arsine	oxygen difluoride
boron trifluoride	phosgene
chlorine pentafluoride	phosphine
chlorine trifluoride	phosphorous pentafluoride
cyanogen chloride	selenium hexafluoride
diborane	stilbine
dinitrogen tetroxide	sulfur tetrafluoride
fluorine	tellurium hexafluoride
germane	
hydrogen selenide	
nitrogen trioxide	

Inhalation Hazards as listed by the DOT. When working with chemicals that have a high degree of acute toxicity:

1. Consult the MSDS, LCSS or other appropriate sources of information for toxicological properties, special precautions, recommended protective equipment and apparel, waste handling procedures, decontamination procedures, and emergency responses

2. All areas in the Division are required to maintain a list of particularly hazardous substances including compounds with a high degree of acute toxicity.
3. The laboratory worker must obtain permission from the laboratory supervisor prior to initiating any process involving compounds with a high degree of acute toxicity.
4. In all experiments involving compounds with a high degree of acute toxicity, the amounts of material used and the names of workers involved should be kept as part of the laboratory notebook.
5. All processes involving compounds with a high degree of acute toxicity in quantities greater than 10 mg must be done in a **DESIGNATED AREA** with a highly visible sign reading: **DESIGNATED AREA FOR USE OF COMPOUNDS WITH A HIGH DEGREE OF ACUTE TOXICITY- AUTHORIZED PERSONNEL ONLY.**
6. Compounds with a high degree of acute toxicity should be stored properly with a label such as **WARNING COMPOUNDS WITH A HIGH DEGREE OF ACUTE TOXICITY** in a designated area. If they are volatile they should be stored in a secondary tray or container in a ventilated storage area (under a slightly negative pressure).
7. Avoid skin and eye contact by wearing eye protection, suitable gloves and laboratory coats or aprons and any other protective apparel suggested in the MSDS or LCSS.
8. Any compounds with a high degree of acute toxicity that can generate dust, vapors or aerosols must be handled in a suitable containment device, such as a fume hood or glove box, in a designated area.
9. Equipment used for compounds with a high degree of acute toxicity should be isolated from general laboratory equipment.
10. Vacuum pumps should be protected by high-efficiency scrubbers or HEPA filters and vented into an exhaust hood.
11. Hazardous wastes involving compounds with a high degree of acute toxicity must be disposed of in accordance with the procedures in the section on Hazardous Wastes and have an identifying label such as **HIGHLY TOXIC.**
12. After work in an area designated for substances of a high degree of acute toxicity is complete, the area must be decontaminated. All equipment including personal protective equipment must not be removed from the designated area without decontamination.

WORKING WITH LABORATORY EQUIPMENT AND PROCEDURES

Many types of laboratory equipment and common laboratory processes have inherent risks associated with them. For example, there is always a risk of explosion or implosion when working under conditions of elevated or reduced pressures. Highly exothermic reactions can become violent unless there is means of cooling. In this chapter of the Safety Manual are safety guidelines for using common equipment and devices used for temperature and pressure control and other miscellaneous laboratory equipment.

WATER COOLED EQUIPMENT

Using cooling water in laboratory equipment such as condensers is a common laboratory practice. The tubing used to supply the water can become disconnected creating an annoying flood hazard. To minimize the flooding hazard:

1. Be sure that tubing is securely fastened. Water pressure in the building can vary and tends to increase after hours.
2. Inspect the hose material frequently as the hoses can deteriorate and break after long term use.
3. Keep sink drains free as exit hoses have a tendency to jump out of the sink.
4. Use plastic locking disconnects for easier connection of water lines while leaving secured lines in tack.

COOLING BATHS AND COLD TRAPS

Commonly used cooling baths include ice water and salt and ice. When it is necessary to reach lower temperatures, dry ice and an organic liquid are often used. Using cryogenic coolants must be done with caution. The following guidelines are intended to minimize the hazards associated with using cooling baths and cold traps:

1. Cooling liquids used with dry ice should be nonflammable and have a low volatility.
2. When preparing a dry ice cooling bath add the dry ice to the liquid or the liquid to the dry ice in small increments.
3. When handling dry ice or any other cryogenic coolant, use gloves and a face shield.
4. When using cold traps in a vacuum system, make sure that the trap is large enough and cold enough to collect the condensable vapors.
5. Check cold traps frequently to make sure that they do not become plugged with frozen material.

6. When using a cold trap in a reduced pressure system, the trap should be taped or placed in metal can filled with vermiculite.

LABORATORY OVENS

Ovens are commonly used for drying glassware and removing solvents from samples. Except for vacuum drying ovens, most ovens do not have a means of preventing volatilized material from being released into the laboratory atmosphere which can result in potential exposure situations. In addition, it is possible that explosive mixtures can form inside the oven. Precautions that should be observed when using ovens include:

1. Unvented laboratory ovens should not be used to dry samples that are volatile and toxic.
2. Glassware that has been rinsed with an organic solvent should not be dried in an oven unless it has also been rinsed with distilled water.
3. If a mercury thermometer breaks inside an oven, the oven should be closed and turned off immediately.
4. If there is a mercury spill in an oven, it should be cleaned up and the oven monitored until the mercury vapor concentration is below the PEL.

OIL AND SAND BATHS

Extreme care must be taken when using oil or sand baths for heating purposes. Serious injuries, such as burns, can result due to the splattering of hot material. Overheated oil can easily burst into flames. When using oil or sand baths:

1. Avoid spilling water or other volatile substances into the bath.
2. Any hot oil spilled should be contained.
3. All oil baths should be labeled with the oil used and its safe working temperatures.
4. If oil baths must be left unattended, they must have a warning label and a high temperature shut off.

REDUCED PRESSURE OPERATIONS

The risk of implosion and flying glass, splattering chemicals and fires is always present when working under conditions of reduced pressure. Large pressure differences tend to develop in equipment operating at reduced pressures which can force liquids into unwanted areas such as vacuum pumps. To work safely under reduced pressure:

1. Vacuum lines should be trapped.
2. Apparatus under reduced pressure should be shielded.
3. If there is a possibility that water, solvents or corrosive gases can be drawn into the building vacuum system the apparatus should be set up so there is a water

aspirator with a solvent collection device and a trap between the aspirator and the apparatus.

4. When using vacuum pumps, a cold trap should be placed between the pump and the apparatus.
5. If possible, exhausts from vacuum pumps should be vented into a hood.

HIGH PRESSURE OPERATIONS

The main risk associated with operations carried out at high pressures is that of explosion. Care must be taken in designing high pressure processes. When work at high pressures:

1. Use appropriate safety shields when performing operations at high pressures.
2. High pressure procedures should only be done using apparatus designed for the particular purpose.
3. When selecting a high pressure vessel, it should be strong enough to withstand the operating pressures and must not react with the materials in the process.
4. Closed systems should not be used to carry out reactions unless the system has been designed and tested to withstand the operating pressures.
5. Pressure equipment should be inspected and tested on a regular basis.

HIGH PRESSURE HYDROGENATION

When performing hydrogenation reactions above one atmosphere, it is necessary to take special precautions in addition to those for handling gas cylinders and flammable gases. Only apparatus designed for the intended application should be used. It is important to work in a well ventilated area and use shields or barricades when there is a possibility that a reaction may run out of control. Experimental work should be designed to avoid conditions which may lead to an explosive situation. The following guidelines should be observed when performing hydrogenation reactions at high pressures:

1. All safety precautions for handling gas cylinders and flammable gases should be observed.
2. Only use high pressure apparatus that has been designed for the intended application.
3. Carefully review the operating procedures for the reactor or high pressure apparatus before use.
4. Equipment should be maintained in good condition and periodically tested.
5. Apparatus should be inspected before each use.
6. The chemistry of the process should be known so that any possible violent reactions may be anticipated and appropriate precautions taken.
7. The reaction vessel should never be filled to more than three fourths of the available free space.
8. Before hydrogen is added to the system it should be purged to remove oxygen avoiding the possibility of producing an explosive mixture.

9. The equipment should only be operated within the designed pressure and temperatures limits. It is advisable to operate within a limit of seventy five percent of the pressure rating.
 10. Only work in a well-ventilated area. It is best to work near a hood or exhaust fan so that any released gases can be discharged safely.
 11. There should be no open flames in the work area.
 12. If there is any possibility that a reaction may run out of control, protective shields or barricades should be used.
 13. After completion of an experiment, the system should be purged of hydrogen.
-

ELECTRICAL HAZARDS

There are inherent dangers involved when using any electrical equipment and therefore care must be exercised when operating and especially when installing, modifying, and/or repairing any electrical equipment. Electrical shock-the passage of current through the human body-is the major electrical hazard. The diverse types of electrical equipment used in the chemistry department includes lasers, power supplies, electrophoresis apparatus, electrochemical set ups, X-ray equipment, hot plates and heating mantles. Work involving any of these various classes of equipment can lead to serious injuries if prudent electrical practices are not followed. In order to assure the safe operation of electrical equipment, it must be installed and maintained in accordance with the provisions of the National Electric Code (NEC) of the National Fire Protection Agency. A copy of the National Electric Code can be found in the Department of Environmental Health and Safety.

Modifications and repairs to the receptacles and wiring in the walls is the responsibility of Facilities Management and should not be attempted or carried out by anyone else. Also, it is strongly advised that qualified personnel carry out all work on electrical equipment. Before attempting any minor repairs, modifications, or installations of electrical equipment it is required that the equipment be deenergized and all capacitors safely discharged. Furthermore, this deenergized and/or discharged condition must be verified before proceeding.

PROPER WIRING

The installation, replacement, modification, repair or rehabilitation of any part of any electrical installation must be in compliance with NEC standards, which specify the proper wiring. For any piece of electrical equipment, there must be a switch in a convenient and readily accessible location that will disconnect the main power source to the apparatus in the event of an emergency. Temporary wiring should only be used when absolutely necessary and must be replaced with permanent wiring with permanent wiring as soon as possible. Temporary wiring must also comply with NEC codes. Extension cords must be used only as temporary wiring for portable equipment. For permanent equipment, permanent wiring should be installed.

GROUNDING

All equipment should be grounded and fused in accordance with NEC codes.

INSULATION

All electrical equipment should be properly insulated. The Electronics Shop should replace any power cords that are frayed and any exposed hot wires should be insulated to

prevent the danger of electrical shock due to accidental contact. When working with high voltage equipment, properly rated gloves and matting for electrical protection should be used. When in doubt, consult the Chemistry Department.

ISOLATION

All electrical equipment or apparatus that may require frequent attention must be capable of being completely isolated electrically. All power supplies must be encoded in a manner that makes accidental contact with power circuits impossible. In every experimental setup, an enclosure should be provided to protect against accidental contact with electrical circuits. This applies to temporary arrangements as well.

PERSONAL SAFETY TECHNIQUES

The following safety procedures should always be followed:

1. Before servicing electrical equipment in any way its power source must be disconnected to avoid the danger of electrical shock.
2. Before reconnecting electrical equipment to its power source after servicing it is strongly recommended to test the equipment with a multimeter to assure that it is grounded.
3. Prudent electrical practices also suggest to properly fuse all electrical equipment to protect the user from electrical shock.
4. Work with a partner who is trained in CPR when installing, replacing, modifying, repairing, or rehabilitating any part of any electrical installation.

EMERGENCY PLANNING AND RESPONSE

Even minor emergencies are of great concern in the laboratory setting. Laboratories generally have a high hazard level. Often, there are many solvents or chemicals that can be explosive. The possibility of dangerous reactions between incompatible chemicals also exists. There is the potential for flash fires and explosions. With the high fuel load likely in laboratories it does not take long for a small fire to quickly spread. Also, in the event of a fire there is the potential for producing unknown toxic products.

Chemical spills and releases are always a possibility in the laboratory work area. Depending on the nature of the material spilled or released, there is the potential for chemical overexposure, fires or explosions. When hazardous materials are spilled or released, the situation can be life threatening.

EMERGENCY PLANNING

The laboratory worker should always work in a manner that minimizes the probability of an accident occurring. Following proper housekeeping, minimizing materials, storing solvents properly, using personal protective equipment, and using engineering controls will reduce the chances of an accident occurring. However, accidents can still happen and one must always be prepared for this possibility.

Planning and preparation are essential. In planning procedures, the possible hazards in the work area, the consequences of potential spills, emergency response information, the location and availability of emergency equipment, location of exits, and the emergency telephone numbers must be known. The measures that one can take in preparing for emergencies include:

- designating emergency coordinators or lab safety officers for your work area.
- posting emergency telephone numbers by all of your telephones.
- knowing the location of emergency equipment and spill kits.
- knowing the possible hazards, emergency response information and spill cleanup procedures before beginning an experimental procedure.

Emergency Telephone Numbers

Emergency Telephone Numbers shall be posted near each telephone and shall include:

- FIRE DEPARTMENT 911
- POLICE DEPARTMENT 911
- AMBULANCE 911

Emergency Equipment

Fire Extinguishers

While it is College policy that personnel are not required to extinguish fires, appropriately trained personnel may attempt to extinguish fires under certain circumstances. All laboratories are equipped with dry chemical extinguishers. Laboratory personnel should be familiar with the location, use and type of fire extinguishers in their work area.

Planning

Proper experimental planning and attention to laboratory details are essential in emergency preparedness. Emergencies, such as spills or fires, are most likely to occur during an experiment, in the transport of materials and during storage. Following all of the safety guidelines for chemical transport and storage along with good housekeeping will minimize the possibility of an accident occurring.

When planning an experiment always consult an MSDS or other appropriate reference material for exposure limits, fire and explosion hazard data, health hazard data, reactivity hazard information, spill cleanup procedures, and emergency first aid. Of particular concern in safety planning are oxidizing and reducing agents, corrosives, reactive chemicals, air sensitive substances, and highly toxic materials. Know the potential problems and the appropriate response before beginning an experimental procedure.

EMERGENCY RESPONSE

The proper response to an emergency situation is essential. An inappropriate response can lead to a situation far more hazardous than the original emergency. Some, though not all, chemical spills and fires will require outside assistance. The following sections are intended to provide guidance in emergency response.

Evacuation

The building should be evacuated in the event of an emergency and the Emergency Action Plan should be followed unless circumstances predict otherwise. If a police, fire

or haz-mat official tells you to evacuate you are required to leave the building. Failure to evacuate when requested by authorities can result in arrest.

Do not return to an evacuated building unless told to do so by Campus Safety and Police.

Fires

Fires in areas where there are chemicals are potentially very dangerous. Besides the rapid spread of fires in areas where there is a large quantity of stored chemicals and the potential for explosions, there is always the possibility of producing highly toxic unknown vapors during chemical fires. Approaching chemical fires must always be done with extreme caution.

While it is College Policy that personnel are not required to extinguish fires, appropriately trained personnel may attempt to extinguish fires under certain conditions. Personnel should only attempt to extinguish fires set forth in the Fire Standard Operating Guideline under the Emergency Action plan located in the Belmont Abbey College Health and Safety Plan, unless otherwise directed .

Use and Types of Fire Extinguishers

There are different types of fire extinguishers available. Not all fire extinguishers are suitable for all types of fire. A summary of the common types of extinguishers and their suitability for use and precautions is given in **Table XX**.

In attempting to extinguish a fire make sure that it is safe to do so and remember that an extinguisher is only a first aid tool and should not be used to control large fires. Fire extinguishers are intended for small isolated fires only. The extinguisher only has about 10 to 30 seconds of spray and is only effective over a short distance of about 5 to 10 feet.

In using a fire extinguisher, make sure that the exit is always within reach. Be careful not to trap any persons on the other side of a fire. It is best to have more than one individual present when attempting to extinguish a fire. Do not take any chances.

It is helpful to remember the acronym "P.A.S.S." when using an extinguisher.

P Pull the Pin

A Aim at the base of the flames

S Squeeze the trigger while holding the extinguisher upright

S Sweep from side to side

Whenever a fire extinguisher is discharged it should be inspected and recharged. Facilities Management inspects and tags fire extinguishers annually.

Individuals are not required to fight chemical fires and have the right to call 911 and activate the building alarm.

Emergency Response to Fires

If there is a fire in an individual's laboratory or work area, the first concern should be for the safety of all individuals in the area. The area should be evacuated immediately regardless of who attempts to extinguish the fire. In the event of a fire follow the Fire Standard Operating Guideline under the Emergency Action Plan located in the Belmont Health and Safety Manual, unless otherwise instructed by Campus Safety and Police.

Chemical Spills

It is always possible for a chemical spill to occur in a laboratory even when following all the chemical hygiene rules and working safely. Most of the time, spills in the laboratory involve relatively small quantities of materials. However, even small amounts of highly toxic or highly reactive materials can be life threatening and dangerous. Laboratory personnel can clean up some spills, if personnel is trained and equipped. However, there are a number of circumstances that indicate that outside assistance should be requested.

If there is a chemical spill in the work area or if a spill is discovered in another area follow the Chemical or Radiation Spill Operating Guideline, unless otherwise instructed by Campus Safety and Police.

Assessing the Spill

Laboratory personnel can cleanup low hazard level spills if personnel is trained and equipped. Low hazard level spills are those spills that do not spread rapidly, do not endanger people and do not endanger the environment. All other spills are high hazard level spills and require outside assistance.

The existence of a number of conditions indicate that outside assistance should be requested as suggested below:

CALL 911

- spills involving medical treatment
- spills involving fire or explosion hazards
- spills that are potentially life threatening
- spills occurring after hours

If none of the above conditions exist, laboratory personnel can clean up the spill. Otherwise call either 911 and follow the Chemical or Radiation Spill Operating Guideline unless instructed otherwise by Campus Safety and Police. An incident form must be filled out for all spills regardless of who cleans it up and filed with Campus Safety and Police.

Reporting the Spill

- When reporting a spill to 911, information about the situation will be requested. This information is necessary so that a proper assessment of the spill can be made and includes:
 - name, telephone number and location
 - location, time and type of incident
 - name and quantity of material involved
 - extent of any injuries
 - possible health and environmental hazards
 - other hazards in the area such as large quantities of stored chemicals, radioactives, biohazards etc.
 - safest route of approach to the incident

Release of Toxic or Explosive Material

In the event of a release of toxic or explosive materials, follow the evacuation plan, unless instructed otherwise by Campus Safety and Police.

Chemical Spill Cleanup

When cleaning up a low hazard spill the proper clean up procedure must be known. If experimental work has been properly planned, this information should be readily available. The appropriate personal protective equipment should be worn and any hazardous waste should be disposed of appropriately. The following guidelines are intended to aid in chemical spill cleanup:

1. The spread of dusts or vapors can be prevented by closing the laboratory door and increasing the ventilation (for example, through the fume hood).
2. The spread of a liquid spill can be controlled by making a dike around the edges of the spill using absorbent materials such as vermiculite or spill pillows.
3. Special absorbents are required for some chemicals such as hydrofluoric acid and concentrated sulfuric acid.
4. If flammable liquids are spilled, remove all potential sources of ignition if it can be done safely.
5. In cleaning spills involving direct contact hazards, select personal protective equipment resistant to the chemical. It is a good idea to wear two sets of gloves.
6. Acid spills can be neutralized with soda ash or sodium bicarbonate.
7. Base spills can be neutralized with citric acid or ascorbic acid.
8. Cleanup residues should be placed in a plastic bucket or other suitable container and disposed of through the Chemical Waste Program.

Power Outage

While a power outage is generally not thought of as being an emergency, hazardous situations can develop if there is a loss of power. When there is a power loss, fume hoods and the ventilation system will not necessarily function properly. If one is in the process of an experimental procedure and there is a power outage, there is the risk of toxic vapors accumulating. The situation can easily become hazardous.

In the event of a power outage, evacuate the building and follow the Chemical or Radiation Spill Standard Operating Guideline on page 29 under the Emergency Action Plan, unless instructed otherwise by Campus Safety and Police.

Injury

In the event of an injury:

1. If the injury is minor, students should go to the Student Health Services and employees should go to Cox Road Urgent Care, 603 Cox Road, Gastonia, NC 28054 and be ACCOMPANIED BY ANOTHER PERSON.

In case of serious injury, DIAL 911 and describe the injury and your location.