Laboratory Safety Manual

Chemical Control Centre

Contents

University of Windsor Health and Safety Policy Statement

The University of Windsor Health and Safety Policy Statement is posted on the Health & Safety Bulletin Boards located across campus and as well as on the Electronic Health & Safety Board, which can be found at:

http://www1.uwindsor.ca/safety/

Laboratory Safety

Introduction

The University of Windsor is committed to providing a safe laboratory environment for its faculty, staff, students and visitors. The goal of the University Laboratory Safety Manual is to minimize the risk of injury or illness to laboratory workers by ensuring that they have the information, training, support and equipment needed to work safely in the laboratory.

This manual gives an overview of general laboratory safety principles, references and resources for more specific safety information, and details about several support programs, such as the hazardous waste disposal program. The manual is to be used as a resource to help conduct teaching and research safely. It cannot be assumed that the warnings or rules laid out in this manual are necessarily complete for dealing with specific chemical or physical hazards; additional information or measures may be required and the appropriate information sources should be consulted.

The Chemical Control Centre (CCC) provides training, resources and consultation for a variety of laboratory safety issues, including chemical safety, laser safety, biological safety, radiation safety, electrical safety and other topics. The CCC web page offers a wide range of resources for many aspects of laboratory safety.

Responsibilities

Safe Laboratory Practices are the responsibility of everyone who conducts research or teaching at the University of Windsor. It is the responsibility of individual supervisors to ensure that the necessary procedures and protocols are both established and followed in their respective work areas. It is the responsibility of research personnel to follow prescribed procedures and protocols when dealing with hazards in the laboratory.

Personal safety depends upon a positive attitude towards safety as well as good, informed judgment on the part of each individual working in the given laboratory. Most health and safety problems in the laboratory can be avoided by practicing good housekeeping and common sense based upon informed knowledge of the hazards. A safe working environment is achieved through responsible and self-motivated activity.[1]

Everyone at the University, regardless of their role, is expected to take initiatives on health and safety issues and to work to solve problems and make continuous improvements in our laboratories. Each person does this both as an individual and in co-operation with others as we share joint responsibility for identifying and resolving health and safety issues.

Supervisors

According to the Ontario Health and Safety Act (OH&S Act of Ontario Sec. 1) a 'Supervisor' is "*a person who has charge of a workplace or authority over a worker".* Within the laboratories at the University of Windsor, 'Supervisors' are defined as faculty members, laboratory technicians, managers, coordinators, teaching/graduate assistants or course instructors who are in charge of a laboratory.

[1] Faculty of Engineering, University of Windsor, Laboratory Safety Manual

The Principle Investigator of each academic unit will appoint a supervisor for each laboratory within his/her department. These faculty members are responsible for all matters of health and safety within their laboratories and will keep the records pertaining to health and safety for the lab. The Department Head is responsible for all teaching laboratories in his/her respective department.

Supervisors have a variety of responsibilities to ensure the safety of those they supervise. Many of the general responsibilities are outlined below. It is important to note that each laboratory is specific and responsibilities may not be limited to those listed.

Supervisor Responsibilities:

- Ensure that an appropriate safety orientation has been given and documented to all individuals when they are first assigned to a laboratory space or prior to starting their first experiment.
- Ensure that all individuals working the laboratory have successfully completed WHMIS training (www.uwindsor.ca/whmis). All students are required to complete the University of Windsor's Laboratory Awareness Training for Undergraduate Students (www.uwindsor.ca/labsafety).
- Ensure that adequate emergency equipment is in proper working order and readily available.
- Ensure that an incident investigation report is completed for every incident or injury that occurs in his/her laboratory.
- Ensure that safety and housekeeping of the laboratory are regularly conducted and recorded. Report and Address all deficiencies to the appropriate departments.
- Ensure that an appropriate alternate is appointed as supervisor when the laboratory supervisor is absent. In a teaching laboratory where safety is a concern, the supervisor or alternate, such as a laboratory instructor, must always be present. In a research lab, an alternate will be appointed when the supervisor is away from campus.
- Ensure that all individuals working within their laboratory have appropriate personal protective equipment (PPE) (e.g. Laboratory coat, eye protection, gloves, footwear).
- Ensure appropriate cautionary signs are posted and maintained.
- Include safety as an agenda topic at regular meetings.

Laboratory Personnel

Laboratory personnel are defined as all individuals who perform procedures and or experiments in a laboratory, such as undergraduate and graduate students, postdoctoral fellows, faculty members and staff members. It is possible that some workers may also have supervisory duties. Laboratory personnel have a variety of responsibilities to ensure their safety. Many of the general responsibilities are outlined below. It is important to note that each laboratory is specific and responsibilities may not be limited to those listed.

Laboratory personnel Responsibilities:

- Follow all applicable safety rules and practices as outlined in this manual.
- Use appropriate personal protective equipment according to instructions provided by both manufacturer and supervisor.

- Report all incidents and observations to the laboratory supervisor no matter how trivial it may seem.
- Report all unsafe conditions to the laboratory supervisor.
- Attend all training courses, as directed by their supervisor.

Laboratory Instructors

Laboratory instructors are individuals who supervise, under the direction of a Faculty member or Department Head, within a given academic unit. These individuals have additional training and knowledge related to the individual experiments that are being conducted. Laboratory Instructors have a variety of responsibilities to ensure the safety of those they instruct. Many of the general responsibilities are outlined below. It is important to note that each laboratory is specific and responsibilities may not be limited to those listed.

Laboratory instructors responsibilities:

- Following all applicable safety rules and practices as outlined in this manual and by the supervisor.
- Be familiar with the University of Windsor and Departmental safety instructions.
- Use appropriate personal protective equipment as stipulated by the laboratory supervisor, Department Head or campus policies.
- Report all accidents, dangerous incidents (i.e. "near misses"), or suspected occupational illnesses to their immediate supervisor without delay.
- Refrain from manipulating any hazardous materials prior to completing the appropriate safety training or receiving specific safety instructions.

Visitors

All laboratory visitors must be accompanied by a University of Windsor representative and follow the rules and procedures of the individual laboratory.

Health and Safety

"The Office of Health & Safety is committed to providing a safe and healthy work and educational environment for all of its employees, students, and visitors."

This includes:
Managing the university's overall health and safety program with the goal of preventing occupational injuries and illness.
Developing and implementing policies and procedures to meet all of the requirements, duties, and standards set by the Occupational Health & Safety Act and its applicable regulations.[2]

[2] Occupational Health and Safety website www.uwindsor.ca/safety

Chemical Control Centre

The Chemical Control Centre (CCC) is part of the Office of Health and Safety and is committed to promoting the safe use of hazardous materials by the university community through the controlled acquisition, distribution, disposal and training services[3].

The Chemical Control Centre is responsible for ordering, receiving, tracking, collecting and disposing of all hazardous materials and products on campus. In addition the Centre provides a variety of training, manuals and other materials and information to facilitate safe laboratory practices across campus.

General Inquires:
In person: Essex Hall B-37
(p): (519) 253-3000 ext. 3523
(f): (519) 973-7013
(e): ccc@uwindsor.ca

www.uwindsor.ca/ccc

[3] Chemical Control Centre website www.uwindsor.ca/ccc

General Laboratory Safety Principals

General Guidelines

Everyone entering or using a laboratory has a responsibility for safety. These responsibilities ensure the safety of each laboratory and persons therein. It is important that all policies, procedures and guidelines are followed.

All individuals working in a laboratory must have completed University of Windsor's General WHMIS training program.
All students working in a laboratory must have completed laboratory safety training program for end-users.

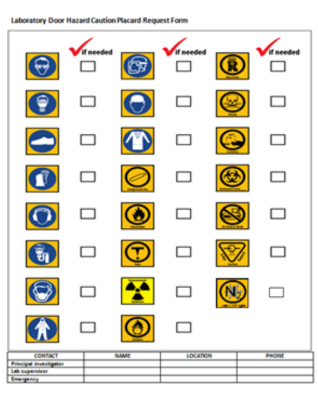
General Guidelines:

- Access to laboratories on campus is restricted to individuals who have been authorized by the laboratory supervisor. Under no circumstances are children permitted in labs. Visitors must be equipped with appropriate safety equipment before entering the lab.
- Never engage in pranks, practical jokes or other acts of mischief.
- Report hazards and accidents immediately to the supervisor and/or laboratory instructor.
- Avoid disturbing or distracting another worker while they are performing a laboratory task.
- No bicycles, rollerblades or pets are allowed within the laboratories.
- Walk; do not run, in the lab.
- Do not sit or stand on laboratory benches at any time.

Laboratory Placards

Laboratory door placards communicate the hazards present in the laboratory to all employees, students, visitors and emergency responders. Door placards are posted on all laboratory entrances and lab service areas where hazardous materials are used or stored. The information on the caution placard is provided by the **Principal Investigator (PI)**.

An example of a caution placard is shown below.



Placard Request

Placards and hazard labels are available free of charge at the Chemical Control Centre. Should you require a new placard or revisions to your existing placard please fill out the **Laboratory Door Hazard Caution Placard Request Form** and submit it to the Chemical Control Centre**.** The CCC will prepare the placard and post it on your laboratory door. Contact the CCC at 519-253-3000 ext 3514 with any questions.

Preparing for Laboratory Work

- Familiarize yourself with safety procedures that apply to the work being done. Ask your supervisor and/or laboratory instructor if you do not understand.
- Know the procedure to follow in case of an accident.
- Be familiar with the locations and use of emergency equipment including the telephone, fire extinguishers, activation of fire alarm, fire blankets, safety showers, and eye wash stations.
- Know the emergency exits, evacuation routes and campus emergency telephone number (from a campus phone, dial **911** – Campus Community Police).
- Read operating instructions or ask for training by the technician or supervisor before operating any equipment. Always use the equipment for approved uses only.

Evaluating Laboratory Hazards… an Ongoing Process

All labs by their nature are filled with hazards. It is essential to recognize and know these hazards to reduce risks to all working within the laboratories. Once you have identified and controlled all current risks, it is critical that you remain open to the possibility that new unexpected dangers can arise.
Laboratory hazards fall into several categories:

- **Chemical**: flammable, toxic, oxidizing, reactive, corrosive chemical products.
- **Biological**: viruses, bacteria, parasites, fungi.
- **Radiation**: radioisotopes, x-rays, lasers.
- **Physical**: glassware, sharp objects, compressed gases, fire, electrical, ionizing, non- ionizing radiation, excessive noise or heat.

The key to protecting yourself and others from laboratory hazards is to be aware of the many types of hazard present and to be trained to handle them properly.

The Chemical Control Centre creates Laboratory Safety Bulletins (LSB) to communicate and raise awareness about various issues related to laboratory safety. These LSB are available online at: ***www.uwindsor.ca/labsafety***

During Laboratory Work

It is important to follow the safety procedures and protocols for the work performed within the laboratory to ensure everyone's safety. Many of the general safety procedures are outlined below. It is important to note that laboratory work varies and safety procedures may not be limited to those listed.

- Always wear appropriate **Personal Protective Equipment (PPE)** for the task that you are carrying out (e.g. safety glasses, prescription glasses with side shields, laser goggles, gloves, safety shoes, laboratory coats). Open toed shoes, such as sandals, are not to be worn in the lab.
- Lab coats and closed toed shoes are required to be worn in all laboratories at the University of Windsor. *(see personal protective equipment section)*
- Tie back or otherwise restrain long hair when working with chemicals, biohazards, radioisotopes, open flames, or moving machinery.
- Work only with materials once you know their flammability, reactivity, toxicity, safe handling, storage and emergency procedures.
- Consult the material safety data sheets (MSDS) before working with hazardous chemicals or infectious material and follow the correct handling procedures.
- Never pipette by mouth. Always use mechanical transfer devices.
- Fire doors must be kept closed at all times.
- Automatic (self-closing) fire doors, emergency exits, passageways, emergency equipment (eyewashes, safety showers and fire extinguishers) or electrical panels must not be blocked.
- Windows of laboratory doors are not to be covered. One should be able to notice if someone is in distress and requires assistance.
- Maintain a tidy workplace. Clean and free of unwanted chemicals, biological specimens, radios and idle equipment. Avoid leaving reagent bottles, empty or full, on the floor.
- Smoking, eating, drinking, storing food, beverages or tobacco, applying cosmetics or lip balm and handling contact lenses are not permitted in laboratories.
- Spilled chemicals must be dealt with immediately.
- Waste should be disposed of according to laboratory rules. Ordinary wastepaper in a wastepaper basket, broken glass and other sharp items in a rigid, puncture-resistant labeled container and hazardous wastes according to the 'Hazardous Waste Disposal Guidelines' in the Hazardous Waste Disposal section of this laboratory manual.

Unattended Procedures/Experiments

Although it is recommended to be present in the laboratory during all procedures and experiments it is sometimes unavoidable. In these cases the following procedures shall be followed.

- Unattended procedures/experiments should be kept to a minimum.
- The procedure must be thoroughly reviewed and all known hazards corrected before the procedure can be left unattended.
- An unattended procedure/experiment should be visited periodically and a sign posted outlining the procedure with the name and phone number of a contact person. The sign should indicate the date and time the procedure was commenced and when it is expected to be completed.

Prior to leaving

Before leaving the laboratory perform a safety check and make sure to:

- Shut down the equipment and leave it in a safe condition for the next users. Turn off gas, water, electricity, vacuum and compression lines, and heating apparatus.
- Return unused materials, equipment and apparatus to their proper storage locations.
- Dispose of all waste material properly in a proper waste container. Attach waste label.
- Remove defective or damaged equipment immediately, and arrange to have it repaired or replaced.
- Decontaminate any equipment or work areas that may have been in contact with hazardous materials.

- Leave behind protective clothing (laboratory coats, gloves, etc.) in the laboratory.
- Always wash your hands before leaving the laboratory, even if you are using gloves.
- If you are the last one to leave, ensure that the laboratory door is closed and locked.

Working Alone Policy

In an academic institution, there will be people working after hours and on occasion working alone. In research laboratories special precautions must be taken to prevent injury.

- Working alone should be avoided. Someone must always be within calling distance when a laboratory experiment is being performed.
- Work procedures with hazardous materials must never be done alone; at least one other person must be present at all times.
- The supervisor is to inform personnel of any material or procedure that may not be used by a person working alone. Such as Cyanide.
- The supervisor must ensure that the person is familiar with the procedure being used, that the procedure is reviewed and hazards are known.
- The person working alone must know what to do in case of emergency or help situation (have phone numbers available).

Workplace Hazardous Materials Information System (WHMIS)

The Workplace Hazardous Materials Information System (WHMIS) is a hazard communication system developed jointly by the Canadian federal, provincial and territorial governments, business and labor. WHMIS is directed toward transmitting information from the supplier to the worker. Under WHMIS, there are three ways in which information on hazardous materials are to be provided:

- Labels on the containers of hazardous materials;
- Material safety data sheets (MSDS),
- Worker education and training programs

The suppliers of the hazardous material to the University of Windsor are required to provide the labels and MSDS to the institution. The University of Windsor passes the information on to the laboratory personnel via the Hazardous Materials Information System (HMIS) and provides education programs and training. This information helps laboratory personnel to work safely when using hazardous materials within their labs.

WHMIS legislation requires that employees must be informed about the hazardous materials in the workplace and receive appropriate training to enable them to work safely. University of Windsor general WHMIS training program provides employees with the basic knowledge required for both recognition and safe handling of hazardous materials. If you are asked to use any substance that is not labeled ask the supervisor for the MSDS. This information is your right under the Occupational Health and Safety Act under the WHMIS regulation. You have the "Right to KNOW" if you might be exposed to any potential hazardous material in the workplace.

The term used to describe the hazardous materials that fall under the control of WHMIS is **"Controlled Product**". A controlled product is any product, material or substance that meets the product criteria contained within one of the six WHMIS hazard classes.

Canadian suppliers are required to classify the controlled products they sell. Some controlled products are either partially exempt or completely exempt from WHMIS requirements. In general, products covered by other federal legislation are exempt from federal WHMIS requirements for supplier labels and MSDS.

WHMIS Training

All individuals working in a laboratory are required to have WHMIS training. Training can be obtained online from the University of Windsor website at the following address: http://www.uwindsor.ca/safety This program has been developed to meet the training standards for a generic WHMIS course. Each participant will be required to complete a WHMIS test. The training is valid for a period of 1 year.

Job –specific WHMIS Training

Job-specific training is the responsibility of Principal Investigators and Laboratory Supervisors. Job-specific training must include instruction in safe work procedures that are unique to each laboratory, in handling, storing, and disposing of controlled products. Laboratory employees must also be trained in waste disposal, emergency procedures in the event of an accident or spill and basic first aid instructions.

Labeling

Supplier's Label

Labeling requirements differ depending on whether the containers are supplier or workplace containers. Controlled products from individual supplier must contain a WHMIS supplier label consisting of a hatched border and seven categories of information including:

1. Product identifier
2. Supplier identifier
3. Hazard symbols
4. Risk phrases
5. Precautionary measures
6. First aid measures
7. MSDS references

The information on the supplier label is a reminder about the nature and degree of hazards of the product and encourages safe practices. This supports the laboratory personnel's right to know about hazards to their health. Labels also refer individuals to the MSDS for complete hazard and safety information on the product.

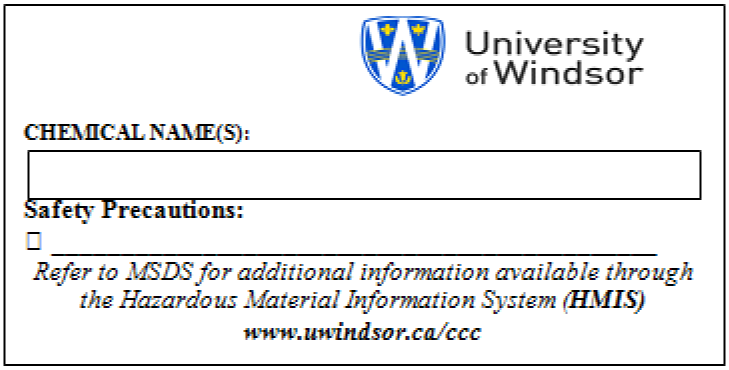
Workplace Label

Workplace labels are required on all decanted portable containers that contain hazardous materials in the workplace. Specifically, the workplace labels are used on:

- storage containers of controlled products produced on site.
- a control product transferred from its original container into.
- secondary container (e.g. a solvent wash bottle, for other than immediate use).
- can also be used on bulk containers if a supplier label is not available.
- can replace a supplier label if this one becomes unreadable, damaged, or detached.

Workplace labels do not need as much information as the supplier label. The University of Windsor Workplace labels provide individuals the ability to communicate the following information:

- Product identifier/chemical name.
- Concentration of chemical.
- Identification of the major hazardous properties based on the WHMIS classification of the product.
- Safety precaution and safe handling procedures.
- Date.


University of Windsor

CHEMICAL NAME(S):

Safety Precautions:

☐ ______________________________

Refer to MSDS for additional information available through the Hazardous Material Information System (**HMIS**)

www.uwindsor.ca/ccc

Figure 3.University of Windsor Workplace Label

The University of Windsor Workplace Label is available free-of-charge from the Chemical Control Centre and the labels come in two sizes to accommodate different containers sizes.

For more information or to request labels please contact:

P: 519.253.3000 ext. 3523

E: ccc@uwindsor.ca.

Laboratory Sample Labels

Samples that are intended to be tested or used solely for educational or demonstration purposes are known as "laboratory samples". The labeling requirements for laboratory samples to be used in a laboratory immediately (same day) and solely by that person who prepared them include:

- the samples must be clearly identified.
- a description of sample's contents must be readily available (e.g., noted in a laboratory book). Material Safety Data Sheets (MSDS) for the sample must be readily available.

Laboratory samples that must be transported outside of a laboratory (e.g., sent elsewhere for analysis), including within the University must have a label affixed to it that contains the following information:

- product identifier (product name)
- owner's name (name of Principal Investigator who prepared the sample)
- laboratory number and building
- emergency telephone number

When samples are greater than 10 kg, the label affixed to the container must meet the requirements of a supplier label. Laboratory samples CANNOT be sent via internal mail. Laboratory samples do not include WHMIS-controlled products that are used by the laboratory for testing other products, materials or substances (e.g., buffer solutions).

Material Safety Data Sheet (MSDS)

A Material Safety Data Sheet (MSDS) is a document, specific to each individual product or material, which is designed to protect users from any hazards which may be associated with the product. The purpose of the MSDS is to relay and explain important information about understanding the hazards and precautions necessary for the safe use of the chemical. Every material that is controlled by Workplace Hazardous Materials Information System (WHMIS) must have an accompanying MSDS.

Supplier Responsibilities

MSDS are prepared and provided by the manufacturers to purchaser of the product at the time of first order and, thereafter, any time the MSDS is revised. MSDS from different manufactures may differ dramatically in organization and appearance yet still present the required data. To help bring order to the MSDS format, an internationally harmonized 16-heading (sections) MSDS format has been developed (see Table 1. below). This format is now used by more and more suppliers and employers and is acceptable under WHMIS.

Table 1 MSDS Sections

International Harmonized Sections		Canadian Categories	
Section 1	Chemical Product and Company Information	Section 1	Product Information
Section 2	Composition/Information on Ingredients	Section 2	Hazardous Ingredients
Section 3	Hazard Identification		
Section 4	First Aid Measures	Section 8	First-aid measures
Section 5	Fire-Fighting Measures	Section 4	Fire or explosion hazard data
Section 6	Accidental Release Measures		
Section 7	Handling and Storage	Section 7	Preventative measures
Section 8	Exposure Controls, Personal Protection and Exposure Limits		
Section 9	Physical and Chemical Properties	Section 3	Physical Data
Section 10	Stability and Reactivity	Section 5	Reactivity Data
Section 11	Toxicological Information	Section 6	Toxicological properties
Section 12	Ecological Information		
Section 13	Disposal Considerations		
Section 14	Transport Information		
Section 15	Regulatory Information		
Section 16	Other Information	Section 9	Preparation Information

Laboratory Responsibilities

All WHMIS controlled product in your work area must have an associated, up-to-date (less than three years old) MSDS' readily available to students, staff, faculty, visitors, and members of the University of Windsor's Central Safety Committee (CSC). MSDS' cannot be kept in locked desks, cabinets, or locked rooms. They must be accessible by all employees and students that work with, or near the controlled product.

There are two formats for MSDS' on campus: (1) Paper and (2) Electronic:

Paper format:

Paper copies must at all times be visible, and accessible in the labs that do not have a computer.

Electronic format:

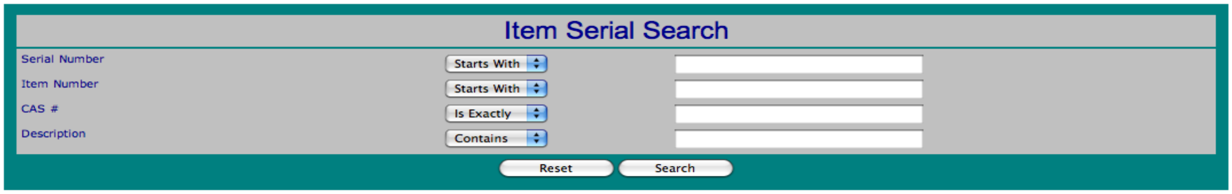
MSDS' for all chemicals/control materials acquired by the Chemical Control Centre (CCC) are available online(www.uwindsor.ca/msds).

For items not acquired by the CCC, electronic copies can be scanned or downloaded from suppliers and provided electronically through a computer to employees and students in the area where the controlled products are used or stored. All individuals must be trained to access these files.

Accessing Electronic MSDSs

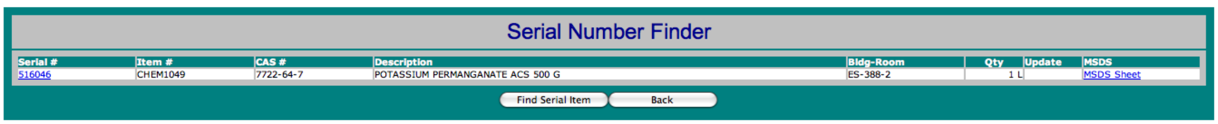
1. Go to www.uwindsor.ca/msds

2. Search for the specific item of interest by: (a) serial number; (b) item number; (c) CAS #; or (d) description.



Search parameters must match exactly. When searching by description, it is recommended that you start using a general search term before searching for specifics.

3. From search results, select "MSDS Sheet" to open a new widow to view .pdf version of the supplier specific MSDS



Select "Back" to refine search perimeters or "Find Serial Number" to update laboratory inventories.

You are strongly encouraged to thoroughly review MSDS' before you begin your work. It is important to remember that whether the MSDS is a paper or electronic copy it must not be older than three years and the product name and supplier on the MSDS must match the material in use. If the MSDS is out of date you can request a current copy from the supplier of the controlled product.

Limitations

Laboratory workers should recognize the limitations of MSDS' as applied to laboratory-scale operations:

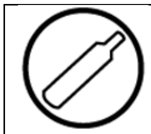
- The quality of MSDS' produced by different chemical suppliers varies widely; therefore, some MSDS' are compromised by vague and unqualified generalizations.
- MSDS' must describe control measures and precautions for work on a variety of scales, ranging from micro scale laboratory experiments to large manufacturing operations. Some procedures outlined in an MSDS may therefore be unnecessary or inappropriate for laboratory-scale work.
- Many MSDS' comprehensively list all conceivable health hazards associated with a substance without differentiating which are most significant and which are most likely to actually be encountered. This can make it difficult for laboratory workers to distinguish highly hazardous materials from moderately hazardous and relatively harmless ones.

For more information on MSDSs, please contact:

Chemical Control Centre
Laboratory Safety, Assurance, and Compliance Group
P: 519.253.3000 ext. 3514
F: 519.973.7013
E: ccc@uwindsor.ca www.uwindsor.ca/labsafety

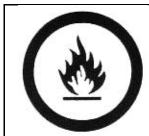
Hazard Warning Symbols

Compressed Gas

	**WHMIS Class:**	A
	Examples:	Hydrogen, Oxygen, Nitrogen

A compressed gas is a gas or liquid that boils at or below ordinary temperatures, in a pressurized container. The gases contained in cylinders can be toxic, flammable, oxidizing, corrosive, inert, or some combination thereof. For more information on Compressed Gases please refer to the Compressed Gases section of this manual.

Flammable chemicals

	**WHMIS Class:**	B
	Examples:	ethyl ether, propane, acetone, lithium hydride

Liquids that pose a fire hazard are grouped as flammable and combustible according to their flashpoints. Generally speaking, flammable liquids will ignite and burn easily at normal working temperatures (i.e., flash points at or below 38^oC or 100^oF). Combustible liquids usually burn at temperatures that are above normal working temperatures (i.e., must be preheated in order to ignite). At normal room temperatures, flammable liquids can give off enough vapors to form mixtures with air that present fire hazards. Spray mists of flammable and combustible liquids in air may burn at any temperature if an ignition source is present. The vapors from most flammable and combustible liquids are heavier than air, these vapors can settle and collect in low areas and present a hazard of flash back. Some flammable and combustible liquids are corrosive. Many undergo dangerous chemical reactions if they contact incompatible chemicals such as oxidizing materials, or if they are stored improperly.

Precautions

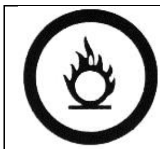
Use the following precautions when working with or using flammable chemicals in a laboratory; keep in mind that these precautions also apply to flammable chemical waste.

- The quantities of flammable liquids kept in the laboratory must be minimized
- Except for the quantities needed for the work at hand, keep all flammable liquids in NFPA approved flammable liquid storage cabinets.
- Use and store flammable liquids and gases only in well-ventilated areas. Use a fume hood when working with products that release flammable vapors.
- Keep flammable solvent containers, including those for collecting waste, well capped. Place open reservoirs or collection containers for organic procedures like HPLC inside vented chambers.

- Store flammable chemicals that require refrigeration in "explosion-safe" (non-sparking) laboratory refrigerators.
- Flammable liquids should only be heated with steam, hot water bath.
- Keep flammable chemicals away from ignition sources, such as heat, sparks, flames and direct sunlight.
- Bond and ground large metal containers of flammable liquids in storage. To avoid the build-up of static charges, bond containers to each other when dispensing.
- Use portable safety cans for storing, dispensing and transporting flammable liquids.
- Clean spills of flammable liquids promptly.

For more information on flammable chemicals visit:
http://www.ccohs.ca/oshanswers/chemicals/flammable/flam.html

Oxidizing Chemicals

	**WHMIS Class:**	**C**
	Examples:	ozone, chlorine, nitrogen dioxide

Oxidizing materials are liquids or solids that spontaneously evolve oxygen at room temperature or with slight heating, or other oxidizing substances (such as bromine, chlorine, or fluorine). This class of chemicals includes peroxides, chlorates, perchlorates, nitrates, and permanganates. Strong oxidizers may cause fire if in contact with flammable and combustible materials, even without a source of ignition or oxygen. Oxidizers can increase the speed and intensity of a fire and cause materials normally noncombustible to burn rapidly, they can also react with other chemicals to produce toxic gases.

For more information on oxidizing chemicals visit:
http://www.ccohs.ca/oshanswers/chemicals/oxidizing/oxiziding_hazards.html

Organic Peroxides

Organic peroxides are a special class of oxidizing compounds with unusual stability problems. Organic peroxides may generally be considered as derivatives of hydrogen peroxides (H_2O_2) in which one or both of the hydrogen atoms are replaced by an organic group. They are hazardous because they are sensitive to shock, sparks, heat, friction and other accidental ignition. They are far more sensitive to shock than primary explosives (TNT). They are low-power explosives and are among the most hazardous substances encountered in the chemical laboratory.

Organic peroxides can be derived from, ethers and ethers derived from alcohols, aldehydes, ketones, vinyl and vinylidene compounds, compounds containing benzylic hydrogen atoms, and compounds containing the allylic (CH2=CHCH2-) structure, including most alkenes.

- Organic peroxides shall be stored in a secure location at the lowest possible temperature consistent with the peroxide's solubility or freezing point.
- Labeled the location to indicate the presence of peroxides.

- Organic peroxides shall not be permitted to contact ignition sources such as heated surfaces, open flames, and sparks or be subjected to solar radiation.
- Quantities of organic peroxides shall be kept to an absolute minimum necessary for immediate needs. Unused materials shall not be returned to the original container.
- Do not use metal tools or spatulas to handle organic peroxides. Ceramic or plastic materials are permitted.
- When handling organic peroxides avoid friction, grinding and impact.
- Solutions of peroxides shall not be used under conditions in which the solvent is vaporized. This condition produces an explosion hazard.
- Organic peroxide should be dated on opening and should not be stored longer than one year since they have a limited shelf life.

Toxic Chemicals

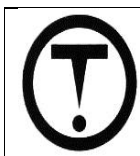
A toxic or poisonous chemical is a material that causes physical harm. Under the WHMIS toxic chemicals are categorized into three classes.

Materials Causing Immediate and Serious Toxic Effects

	**WHMIS Class:**	D1
	Examples:	arsenic, cyanides, styrene

Materials included in this class are generally highly toxic chemicals that cause death within a short period following exposure. Even small amounts can be fatal if inhaled, ingested or absorbed through the skin. Handle only using proper personal protective equipment or work in properly designated areas, avoid breathing dust or vapours, contact with skin or eyes and store only in designated areas.

Materials Causing Other Toxic Effects

	**WHMIS Class:**	D2
	Examples:	asbestos, lead, vinyl chloride, isocyanates

The toxic effect of chemicals grouped in this class generally arises from repeated, long-term chronic exposure. The types of toxic effects are skin and eye irritation, chronic toxicity, sensitization causing skin or respiratory allergies, mutagenicity, carcinogenicity, teratogenicity, emvryotoxicity and reproductive toxicity. A wide variety of chemicals can fall in this class. Consult the Material Safety Data Sheet to determine the nature of the effect.

Biohazardous Infectious Material

	**WHMIS Class:**	D3
	Examples:	blood sample containing the Hepatitis B virus

Biohazardous infectious materials consist of any organisms and the toxins produced by these organisms that have been shown to cause disease or are believed to cause disease in either humans or animals. Blood and body fluids are included into this category. They can potentially contain hepatitis A, B or C viruses or HIV. When working with biohazardous infectious materials, avoid all direct contact, open containers in an appropriate area, ensure training is current, avoid creating or breathing aerosols and disinfect or sterilize area after handling biohazards.

Corrosive Chemicals

	**WHMIS Class:**	**E**
	Examples:	ammonia, fluorine, hydrochloric acid, sulfuric acid, sodium hydroxide

Corrosive chemicals are substances that cause visible destruction or permanent changes in human skin tissue at the site of contact, or are highly corrosive to steel. The major classes of corrosives are Acids, Bases, and other materials with corrosive properties. Corrosive materials pose a serious immediate risk to skin, tissues, eyes and other parts of the body such as respiratory or digestive tract.

The following are some of the general controls and handling techniques that should be used when working with corrosives:

- Wear appropriate personal protective clothing, an acid-resistant apron, chemical resistant gloves, and **splash goggles/face shield.**
- Use proper pouring techniques when pouring acids into water. **A**lways **A**dd **A**cids to water (add slowly).
- Use in the most dilute concentration needed to achieve desired results.
- Use a fume hood for handling, dispensing, mixing, or any other manipulation of corrosive materials known to emit vapours or liberate hazardous reaction products.
- Transport corrosive liquids in unbreakable containers or place glass containers in safety carriers, particularly when passing through public areas.
- Store glass containers of corrosive liquids in spill trays to contain leakage.
- Dilute and mix corrosives slowly if exothermic reaction occurs and heat is liberated.
- Irrigate skin and eyes thoroughly for 15 minutes if contact with corrosive material occurs.
- Separate acids from bases.

Reactive Chemicals Precautions

	**WHMIS Class:**	F
	Examples:	ozone, hydrazine, benzoyl peroxide

WHMIS define dangerously reactive liquids and solids as those that can undergo vigorous polymerization, condensation or decomposition, become self-reactive under conditions of shock or increase in pressure or temperature and react vigorously with water to release a lethal gas.

The most common reactive solids include sodium, potassium and lithium metals; acid anhydrides, acid chlorides and salt hydrides.
Reactive liquids are chemicals that react vigorously with moisture, oxygen or other substances. Examples include organic halides, phosphorous trichloride, titanium tetrachloride, butyl lithium, and hydrazine.

Hazard assessment of work involving reactive materials should address proper use and handling techniques, fire safety (including the need for Class D fire extinguishers), storage, potential peroxide formation, water and air reactivity, and waste disposal issues.
Many reactive materials will liberate hydrogen when they react with water or acids. The use of a fume hood is recommended to prevent the buildup of combustible gases. Glove boxes may be used to handle reactive materials if inert or dry atmospheres are required. Work with as small a quantity as possible, dispose of reactive chemicals once shelf life has expired.

Globally Harmonized System (GHS) Symbols

The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) has been adopted in many countries. Although Canada has not adopted GHS, some international manufactures and suppliers use this system. If you discover a symbol that is not familiar or that is not outlined under WHMIS, please contact the Chemical Control Centre for clarification.

Hazardous Materials Properties

(*Taken from McGill University Laboratory Safety Manual with permission*)

Toxicological properties: LD_{50} AND LC_{50}

Despite the limitations of using toxicity data from animal studies to predict the effects on humans, LD_{50} and LC_{50} values often comprise a large part of the available toxicity information, and form the bases for many standards, guidelines and regulations.

LD_{50} (Lethal Dose$_{50}$) is the amount of a substance that, when administered by a defined route of entry (e.g. oral or dermal) over a specified period of time, is expected to cause the death of 50 per cent of a defined animal population. The LD_{50} is usually expressed as milligrams or grams of test substance per kilogram of animal body weight (mg/kg or g/kg).

LC_{50} (Lethal Concentration$_{50}$) is the amount of a substance in air that, when given by inhalation over a specified period of time, is expected to cause the death in 50 per cent of a defined animal population. Some LC_{50} values are determined by administration of test substances to aquatic life in water. The LC_{50} is expressed as parts of test substance per million parts of air (PPM) for gases and vapours, or as milligrams per liter or cubic meter of air (mg/L or mg/m^3) for dusts, mists and fumes.

When assessing the hazards of materials used in the laboratory, it is important to remember that substances with lower LD_{50} or LC_{50} values are more toxic that those with higher values.

Exposure limits (TLV, PEL)

An exposure limit is the maximum limit of exposure to an air contaminant. The threshold limit value (TLV) or permissible exposure limit (PEL) can be expressed as the following:

- 8-hour time-weighted average (TWA) is the average concentration to which most workers can be exposed during an 8-hour workday, day after day, without harmful effects.
- Short-term exposure limit (STEL), is the maximum average concentration to which most workers can be exposed over a 15 minute period, day after day, without adverse effects.
- Ceiling (C) defines a concentration that must never be exceeded; and is applied to many chemicals with acute toxic effects.

It should be noted that most exposure limits are based on industrial experiences and are not entirely relevant to the laboratory environment. Good laboratory practices and well-designed ventilation systems serve to maintain air concentrations well below these limits.

Flash point

The flash point is the lowest temperature at which a liquid produces enough vapor to ignite in the presence of a source of ignition. The lower the flash point, the greater the risk of fire. The flash point is often used as one descriptive characteristic of liquid fuel, but it is also used to describe liquids that are not used as fuels. Many common laboratory solvents (e.g., acetone, benzene, diethyl ether, and methanol) have flash points that are below room temperature.

Auto-ignition Temperature

The ignition or auto-ignition temperature is the temperature at which a material will ignite, even in the absence of an ignition source; a spark is not necessary for ignition when a flammable vapor reaches its auto-ignition temperature. The lower the ignition temperature, the greater the potential for a fire started by typical laboratory equipment.

Flammable Limits

Flammable limits or explosive limits define the range of concentrations of a material in air that will burn or explode in the presence of an ignition source such as a spark or flame. Explosive limits are usually expressed as the percent by volume of the material in air:

- The **lower explosive limit (LEL)** or **lower flammable limit (LFL)** is the lowest vapor concentration that will burn or explode if ignited. Below this limit, the concentration of fuel is too "lean" for ignition, i.e., the mixture is oxygen rich but contains insufficient fuel.
- The upper explosive limit (UEL) or upper flammable limit (UFL) is the highest vapor concentration that will ignite. Above this limit, the mixture is too "rich" for ignition.
- The flammable range consists of concentrations between the LEL and UEL.

Table 2 Flash points (FP), lower explosive limits (LEL) and exposure limits (8-hour time-weighted averages - TWA) of several flammable or combustible laboratory solvents

Solvent	FP °C	LEL % by volume	Auto-ignition temp °C	TLV-TWA* PPM (mg/ m^3)
Acetic acid glacial	39	4.0	427	10(25)
Acetone	-18	2.5	538	25(590)
Acetonitrile	5.6	3.0	524	2034)
Diethyl Ether	-45	1.9	180	400(1210)**
Ethanol, absolute	13	3.3	423	1000(1900)
Ethyl acetate	-4.4	2.0	427	400(1440)
Methanol	11	6.0	464	200(260)
N-pentane	-49	1.5	309	120(3500)
Toluene	4.4	1.1	552	100(375)

NIOSH Pocket Guide to Chemical Hazards, 1999, Laboratory Safety Manual McGill University, **Pending review

Personal Protective Equipment (PPE)

All laboratory workers must be protected from potential chemical and physical hazards by personal protective apparel and equipment. Personal protective equipment (PPE) acts as a primary barrier between the hazard and the worker. It is the responsibility of anyone working in the laboratory to use the appropriate PPE (Ontario Regulation 851 Sections 79-86). The appropriate type of PPE depend on the task being performed and can be chosen after consulting the most current and applicable MSDS. All the personnel in the laboratory should wear personal protective equipment, not just those actively working.

Laboratory coats, safety glasses and Closed toed shoes are required PPE while working in laboratories at the University of Windsor. Should the activities within your laboratory not require the use of the above PPE, a risk assessment from Health & Safety must be performed which will be assessed by the Research Safety Committee and VP of Research for approval.

Personal protective equipment must not be considered the primary means of protecting the laboratory worker. Research procedures and engineering controls, such as fume hoods, must be considered first. Personal protective equipment includes; hand, eye, skin, respiratory, hearing, foot and head protection. For more details of Personal Protective Equipment please refer to Policy OHS – 4.6.1.

Table 3 Personal Protective Equipment Type

PPE TYPE	DESCRIPTION
Laboratory coats	Must be worn while preforming laboratory work. Must be removed when leaving the lab. Must be kept buttoned. Disposable laboratory coats should not be worn near any source of ignition, these are generally made of polypropylene which melts onto the skin if heated or burned. In clean-rooms or biohazard labs, additional protective clothing is required, including full-body suits, head/hair and shoe coverings.
Aprons	Aprons are chemical or liquid and fire resistant. Use for work with corrosive chemicals, blood borne pathogens and where splatter is possible. Should be easily washed.
Eye protection: protective glasses /goggles / face shields	Approved safety glasses with side shields are the minimum protection required in laboratory. Must be worn while in the laboratory to protect against impact or splashes; Worn when: using chemicals, handling: biological hazards, sparks, open flame and spatters, molten metals, heating test tubes or working with containers under pressure; removing vials stored in liquid nitrogen. Worn in shops for: wood or metal processing, particularly grinding, welding, chipping, sawing and sanding. Prescription eyeglasses and contact lenses do not provide sufficient protection; must have shields.
Specific goggles	Use for UV light or for working with lasers. Must wear specific type, certified and for a proper wavelength range.
Gloves	Use for working with chemicals; handling biological materials; when there is a potential for cuts; when cleaning contaminated equipment; when handling cold/hot materials. Choose correct glove materials using glove charts; choose gloves that provide a good fit; wash hands after removing gloves; ensure that gloves are removed before touching "clean" surfaces. Use metal mesh gloves for protection from cuts.
Foot protection	For all laboratory work wear closed toe and closed heel shoes; avoid canvas shoes. Safety shoes or boots may be required in labs with heavy equipment or materials.
Dust Masks	Use to avoid contamination cultures, dust. Do not provide appropriate protection against aerosolized biological agents.
Respirators	Use to provide respiratory protection when cleaning up chemical spills, when working with biological agents that may be aerosolized. Respirator users must be in good health. Respirators must be fit-tested; training and maintenance requirements should be followed; many types are available; select appropriate respirator based on hazard; follow C.S.A. Z94.4-02 standard.
Earplugs or ear muffs	Use when required to protect against excessive noise exposure.
Head protection	Use for work where there is a risk of injury from moving, falling, or flying objects or when working near high-voltage equipment. Hard hats are designed to protect from the impact and penetration caused by objects hitting the head. Head protection should be chosen according to the hazard and should be properly rated (Industrial Protective Headwear C.S.A.-Z94.1-05)

Gloves

There are many different types of protective gloves available since no single material will protect against all chemicals. Base your selection of proper glove material on:

- identification of the hazardous material and work procedures requiring hand protection.
- flexibility and touch sensitivity required; a need for high tactile sensitivity, for example, would restrict glove thickness, and some protocols may require the use of gloves with non-slip or textured surfaces.
- type and length of contact (occasional or splash vs. prolonged or immersion contact).
- whether disposable or reusable gloves are more appropriate.

Manufacturers can supply specific information on the choice of glove for specific applications.
A glove selection and assessment chart done by the gloves manufacturer Ansell is easy to use and can be found at: http://www.ansellpro.com/specware/guide.asp
Other information on chemical resistance of gloves can be found at:
http://ehs.okstate.edu/hazmat/perm-a.htm
http://www.bestglove.com/site/

The following gloves are available for sale at University of Windsor's Chemical Control Centre:

- **Latex Gloves**
  Recommended for: work with weak acids, weak bases, alcohols, aqueous solutions.
  Not recommended for: oils, greases and organics

- **Clear Vinyl Gloves**
  Recommended for: work with strong acids and bases, salts, other aqueous solutions, alcohols, glycol ethers.
  Not recommended for: aliphatic, aromatic and chlorinated solvents, aldehydes, ketones, nitro compounds.

- **Nitrile Gloves**
  Recommended for: oils, greases, acids, caustics, aliphatic solvents
  Not recommended for: aromatic solvents, many ketones, esters, and many chlorinated solvents.

The gloves stored in the CCC are available in a lightly powdered or powder-free presentation.
The gloves listed above show poor resistance to the following chemicals:

Table 4 Chemicals which are recommended to be handled with VITON gloves

benzene	carbon disulfide
carbon tetrachloride	chloroform
methylene chloride	*n*-pentane
toluene	1,1,1-trichloroethane
xylene	

For these chemicals, a glove material such as *VITON (fluoroelastomer)* shows excellent resistance.Gloves Selection by Laboratory Hazard (see appendix 1)

Personal Protective Equipment Symbols

Symbols may be used to identify the types of personal protective equipment which should be used with a particular hazardous substance. These PPE symbols are used on the University of Windsor Placards across campus. Note that this is not an exhaustive list; if you encounter a symbol you are unsure of contact the CCC for clarification

Table 5 Personal Protective Equipment Pictograms

 **Dust Mask** A NIOSH* approved N95 dust mask must be used.	 **Air Purifying Respirator** A NIOSH approved chemical cartridge respirator must be used. Needed specialized training when using this type of respirator.	 **Supplied Air Respirator** A NIOSH approved SCBA** or Supplied Air system must be used. Needed specialized training when using this type of respirator.
 **Laboratory coat** A laboratory coat made of material resistant to the hazardous material must be worn. Consult your supervisor or the applicable MSDS for further information.	 **Chemical Protective Clothing** Either a hooded or fully-encapsulating suit of appropriate material must be worn. Consult MSDS for proper level of protection. Use of this type of PPE requires specialized training.	 **Goggles** C.S.A. *** approved chemical-resistant, splash-proof goggles must be worn.
 **Face Shield** C.S.A. approved face shield must be worn. Note: C.S.A. approved safety glasses or goggles must also be worn with this device.	 **Foot Protection** C.S.A. approved protective footwear appropriate to the hazard must be worn.	 **Hand Protection** Gloves appropriate to the hazard must be worn. Consult the MSDS for further information.

*/ NIOSH - The National Institute for Occupational Safety and Health is the United States federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness.

**/SCBA - A self contained breathing apparatus, or SCBA, sometimes referred to as a Compressed Air Breathing Apparatus (CABA) or simply Breathing Apparatus (BA) is a device worn by rescue workers

***/C.S.A. - Canadian Standards Association

Compressed Gas Cylinders[4]

Introduction


Figure 11 Gas Cylinders with Cap

Compressed gas cylinders expose users to both **chemical and physical hazards**. The gases contained in cylinders can be toxic, flammable, oxidizing, corrosive, inert, or some combination thereof. Since the chemicals contained in these cylinders are in gaseous form and are pressurized, they can quickly contaminate a large area due to leaks in the cylinder, regulator or any part of the system after the regulator. For this reason, it is necessary to be familiar with the chemical hazards of the gases being used. In addition to the chemical hazard, there are also physical hazards involved from the pressures of the gas as well as the physical weight of the cylinders. Breakage of the head valve or rupture of the cylinder can cause the cylinder to become a rocket or fragmentation bomb.

Safe storage, monitoring for leaks and proper labeling are essential for the prudent use of compressed gases. If the gas is flammable, flash points lower than room temperature compounded by rapid diffusion throughout the laboratory present the danger of fire or explosion. Additional hazards can arise from the reactivity and toxicity of the gas, and asphyxiation can be caused by high concentrations of even inert gases such as nitrogen. An additional risk of simple asphyxiants is head injury resulting from falls following rapid loss of oxygen from the brain. Death can also occur after asphyxiation if oxygen levels remain too low to sustain life. Finally, the large amount of potential energy resulting from the compression of the gas makes a highly compressed gas cylinder a potential rocket or fragmentation bomb. On-site chemical generation of a gas should be considered as an alternative to use of a compressed gas if relatively small amounts are needed. Monitoring compressed gas inventories and disposal or return of gases not in current or likely future use is advisable to avoid the development of hazardous situations.
Only properly trained individuals should handle compressed gas cylinders.

[4] LSB 2008-21 Compressed Gas Cylinder Safety, Laboratory Safety Bulletin, University of Windsor,

TRAINING INFORMATION
The University of Windsor offers "Compressed Gas Cylinder Safety Training". For more information, please visit: www.uwindsor.ca/labsafety

Storage

Figure 12 Gas Cylinders

The following precautions should be taken when storing compressed gas cylinders:

Secured: All gas cylinders, empty or full, must be properly secured using an appropriate material, such as a chain, plastic coated wire cable, commercial straps etc., to secure cylinders. In labs, they must be secured to either a bench, a wall, or to the floor.
Gas cylinders cannot be stored in public hallways, or other unsecured area. Cylinders should be protected against tampering by unauthorized individuals.

Protected: They must be adequately protected from damage. Always place valve protectors on gas cylinders when the cylinders are not connected for use. Do not store cylinders near elevators or gangways, or in locations where heavy-moving objects may strike or fall on them.

- Store cylinder out of direct sunlight and away from sources of heat and ignition; temperatures must not exceed 51°C.
- Storage areas must be well-ventilated, cool, dry, and free from corrosive materials.

Segregated: Cylinders must be segregated based by hazard classes while in storage. Oxidizers must be separated from flammable gases, and empty cylinders should be isolated from full cylinders. Cylinders that contain toxic gases should be placed within ventilated storage cabinets.

Handling

Identification: Contents of the gas cylinder should be clearly identified. Color coding is not a reliable means of identification. Do not deface or remove any markings, tags, used for identification attached by the gas vendor. Cylinders that do not bear a legibly written identification of the contents should not be used.

Best Practices:

- If necessary, cylinders may be rolled on their bottom edge while in a nearly vertical position, but never dragged.
- Avoid dropping cylinders or allowing them to strike violently against other cylinders.
- Do not tamper with safety devices contained within valves or on cylinders.
- Never refill a cylinder. The practice of transferring compressed gases from one commercial cylinder to another is not permitted.
- If an outlet valve becomes clogged with ice or frozen, apply warm water (not boiling) to the valve only if gas is not water reactive. Do not thaw by using an open flame.
- Ensure the tubing and the apparatus downstream from the regulator is designed to withstand the pressure intended to be delivered. The tubing and other components should also be chemically resistant to the gas being used.
- Never use PTFE (Teflon) tape, other lubricants or sealant when installing a regulator. The recommendation of commercial gas suppliers is that the regulator fittings are in good condition and do not require additional sealants.

- Compressed gas cylinders have a finite shelf life. Ensure that cylinders are regularly inspected. Any cylinder which is corroded or has damaged valve components should be returned to the supplier. All cylinders older than ten years should be returned to the manufacturer.

The primary safety rule for handling compressed gas cylinders is that an empty cylinder is never truly empty and therefore should be treated as full.
The same handling rules apply to it that applies to a full cylinder of the same gas. If the gauge reads zero and the cylinder is at sea level, the cylinder still contains gas at 14.7-psi absolute pressure.

Use and Operation

Personal Protective Equipment: Always use safety glasses (preferably a face shield) when handling and using compressed gases, especially when connecting and disconnecting compressed gas regulators and associated supply lines. Never direct gases toward the body. Employ care to avoid injury to hands or feet. It is highly recommended to use safety shoes and heavy gloves.

Regulators: Always use the appropriate regulator that is recommended by the gas provider for the type of cylinder and gas being used.

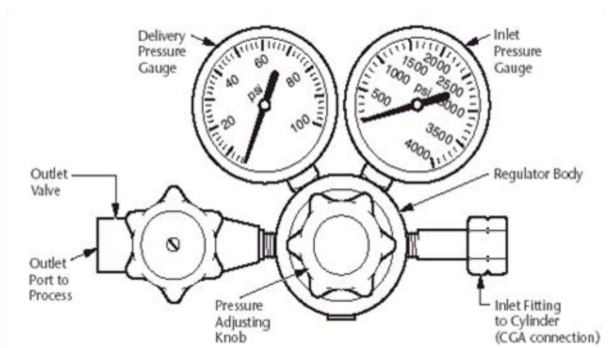


Figure 13 Gas Cylinder Regulator

Best Practices:

- Do not use recessed top of the tank cylinders for the storage of tools or other equipment.
- Do not force open or close cylinder valves.
- Only use wrenches or tools that are provided by the cylinder supplier to open or close a valve. Pliers should never be used to open a cylinder valve. Some regulators require washers; this should be checked before the regulator is fitted.
- Close the main cylinder valve as soon as it is no longer necessary to have it open. Remove all pressure from regulators not currently used (by opening equipment valves downstream **after** the regulators are closed).
- Place a trap between the regulator valve and the reactor vessel to prevent contamination when carrying out chemical reactions using pressurized gas.
- Do not use unnecessarily long hoses. If a long hose must be used, make sure it is free from kinks, and away from high traffic areas. Examine hoses periodically for leaks by submersing sections in water and looking for bubbling.
- Turn off the cylinder valve and then the regulator, when your work is finished. The pressure gauges should be brought back to zero.
- When using toxic or irritating gas, the valve should only be opened while the cylinder is in a working fume hood.
- Fire extinguishing equipment should be readily available when combustible materials can be exposed to welding or cutting operations using compressed cylinder gases.
- Keep the cylinder clear of all electrical circuits, flames and sparks.
- Never bleed a cylinder completely empty; leave a residual pressure.

Transportation

The following precautions should be taken when transporting compressed gas cylinders:

- Use a suitable hand cart or dolly for transporting cylinders. Cylinders must be secured to the cart or dolly by a chain or commercial strap. Lift platforms must be used to move cylinders from one level to another. When cylinders must be handled by a crane or derrick, carry them in a cradle or on a suitable platform and take extreme care that they are not dropped or bumped. Do not use slings.
- Cylinders must be kept upright, secured, and **with the valve cap in placed during transportation.** If space does not allow, cylinders may be laid down and secured and space should be well ventilated.
- **Cylinders should never be transported with the regulator in place.**
- Be careful not to drop cylinders or strike them against each other or against other surfaces violently.
- Never use the valve cover to lift cylinders; they can become damaged and come unattached. If the cylinder is dropped on a hard surface it can cause an explosion.

Leaks

Leaking gas cylinders constitute hazards that may be so serious as to require an immediate call for outside help. Individuals should not apply extreme tension to close a stuck valve. Personal protective equipment should be worn.

The following guidelines cover leaks of various types of gas cylinders:

Flammable, inert, or oxidizing gases: The cylinder should be moved to an isolated area, away from combustible material if the gas is flammable or an oxidizing agent, and signs should be posted that describe the hazards and state warnings. Care should be taken when moving leaking cylinders of flammable gases so that accidental ignition does not occur.

Corrosive gases: Corrosive gases may increase the size of the leak as they are released, and some corrosives are also oxidants, flammable, and/or toxic. The cylinder should be moved to an isolated, well-ventilated area, and suitable means used to direct the gas into an appropriate chemical neutralizer. If there is apt to be a reaction with the neutralizer that could lead to a "suck-back" into the valve (e.g., aqueous acid into an ammonia tank), a trap should be placed in the line before starting neutralization. Signs should be posted that describe the hazards and state warnings.

Toxic gases: The same procedure should be followed for toxic gases as for corrosive gases, but for the protection of personnel, a special warning should be given for the added hazard of exposure. The cylinder should be moved to an isolated, well-ventilated area, and suitable means used to direct the gas into an appropriate chemical neutralizer. Signs should be posted that describe the hazards and state warnings. Appropriate personal protective equipment should be worn.

Cryogenic Liquids and Dry Ice[5]

Cryogenic liquids are materials with extremely low boiling points (less than -73 °C) [1] and are commonly used to obtain very low temperatures. Common examples of cryogenic liquids are liquid nitrogen, helium, argon and air. Slush mixtures of dry ice (frozen carbon dioxide) and isopropanol or acetone which have slightly higher boiling points are sometimes included in this category. Most cryogenic liquids are odorless, colorless, and tasteless when vaporized. When cryogenic liquids are exposed to the atmosphere, however, they create a highly visible and dense fog. Under WHMIS, cryogenic liquids are classified as compressed gases.

Cryogenic Liquid Containers

Cryogenic liquid containers are designed for transportation and storage of liquefied gases at cryogenic temperatures, typically colder than – 90°C. The containers also referred to as liquid cylinders, are double-walled, vacuum vessels, specifically designed to withstand extreme differences in temperature. They contain a large volume of gas at a relatively low pressure compared to a compressed gas cylinder and provide a source of cryogenic liquids which can be easily handled.

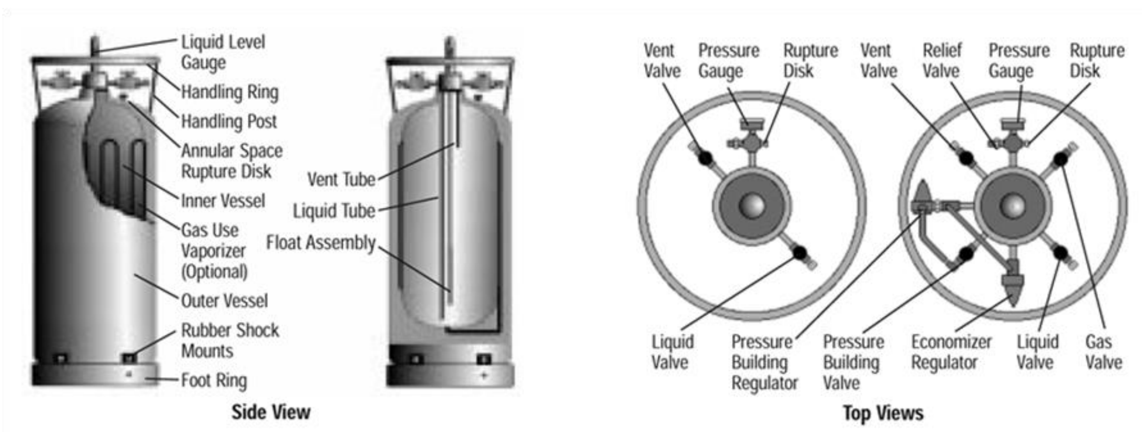


Figure 14 Typical Cryogenic Liquid Container

Source: http://www:safety.deas.harvard.edu/services/nitrogen.html

Dewars

Dewars are equipped with loose-fitting lids or specially vented stoppers. They are not pressurized vessels for holding cryogenic liquids. They are available in variety of shapes and sizes.

Figure 15 Dewars

[5] LSB 2008-2 Handling and Transportation of Cryogenic Liquids, Laboratory Safety Bulletin University of Windsor,

Hazards Associated with Cryogens

There are several physical and health hazards of cryogenic liquids. They are: extreme cold, oxygen deficiency (asphyxiation), toxicity, pressure build-up hazard, and the condensation of atmospheric oxygen.

Extreme Cold Hazard

Cryogenic liquids and their associated cold vapours can produce effects on the skin similar to a thermal burn. Brief exposures that would not affect skin on the face or hands can damage delicate tissues such as the eyes. Prolonged exposure of the skin or contact with cold surfaces can cause frostbite. Prolonged breathing of extremely cold air may damage the lungs. Avoid skin and eye contact, do not inhale cryogenic vapors and ensure the proper personal protective equipment is worn.

Oxygen Deficiency Hazard

Both cryogenic liquids and dry ice undergo substantial volume expansion when converted to a gas phase, (for example, 1 L of liquid nitrogen forms nearly 700 L of nitrogen gas at room temperature) which can potentially lead to an oxygen deficient atmosphere where ventilation is limited. Oxygen deficiency creates an asphyxiation hazard.

The use of dry ice in cold rooms can cause increased breathing, headache, dizziness, nausea and visual disturbances due to elevated carbon dioxide concentrations in the air. Dry ice can also cause asphyxiation in confined spaces**. Only work with cryogenic liquids in well ventilated areas, and do not enter an oxygen deficient atmosphere even to rescue someone.**

Pressure Build-Up Hazard

Over pressurization will develop in inadequately vented pressurized systems due to the expansion of cryogenic liquid vaporizing into large volumes of gas. Sudden release of this pressure can cause personal injury by issuing cold gas or liquid, or by expelling parts, as a result of leaks or bursts. The low temperatures of liquid cryogens also result in their potential to freeze water or other materials rapidly, and subsequent blockage and pressure build-up. Cylinders and other containers such as dewar flasks should be filled to no more than 80% of their capacity.

Toxicity Hazard

Toxic cryogens release toxic gases. For example, liquid carbon monoxide can release large quantities of carbon monoxide gas, which can cause death almost immediately.

Condensation of Atmospheric Oxygen

Cryogenic fluids with a boiling point below that of liquid oxygen (-183.0°C) are able to condense oxygen from the atmosphere and in some cases cause oxygen to accumulate as an unwanted contaminant. For example if a constant stream of air is pulled through a vacuum trap cooled with liquid nitrogen, liquid oxygen may condense in the trap. Similar oxygen enrichment may occur where condensed air accumulates on the exterior of cryogenic piping. Violent reactions such as rapid combustion or explosion may occur if any kind of combustible material makes contact with this oxygen. Liquid oxygen reacts violently with most organic substances, including Teflon® tape, vacuum grease, and organic solvents.

Control of Hazards

Before working with cryogenic liquids, acquire a thorough knowledge of the liquids cryogenic procedures, equipment operation, safety devices, properties and protective equipment usage. Personal protective equipment is important when filling Dewar's or removing specimens or samples from a Dewar. Cryo-gloves, a face shield or safety goggles, a laboratory coat, long pants and closed toed shoes must be worn.

Special Handling Procedures and Storage Requirements

Storage

Dewars are to be stored in well-ventilated areas. Storage in unventilated closets, environmental rooms, and stairwells is prohibited. Liquid nitrogen should normally be used only in a well-ventilated area. However, there may be occasions, example, transport of Dewars in elevators, when this may not be possible. Large Dewars must be anchored to a wall.

Store liquid containers in a well – ventilated place where they are protected from the weather and away from sources of heat. Store flammable cryogenic liquids and liquid oxygen away from combustible materials and sources of ignition. Additionally, follow all substance-specific storage guidance provided in MSDS.

Spill

Minor spill (< 1 liter) - allow liquid to evaporate, ensuring adequate ventilation.
Following return to room temperature, inspect area where spillage has occurred. If there is any damage to the floors, benches or walls, report it to the supervisor/Facilities.
Major release (> 1 liter) - shut off all sources of ignition, evacuate area of all personnel and call the Campus Police ext. 911 for emergency assistance. **DO NOT** return to the area until it has been declared safe.

Waste Disposal

Allow small amounts of unused nontoxic cryogenic liquids such as nitrogen, argon, helium etc., to evaporate in a well vented location remote from work areas. Do not store cryogenic substances or allow them to vaporize in enclosed areas, including: fridges, cold rooms, sealed rooms and basements. Do not pour cryogenic liquids down the sink - they will crack waste pipes causing potentially dangerous leaks.

Solid Carbon Dioxide (dry ice)

Sublimation point -78.5 °C
Melting point -56.6 °C
Apart from being unable to condense oxygen, hazards associated with solid carbon dioxide are similar to those described for liquid nitrogen. In operation, similar precautions should be taken against cold burns and asphyxiation. The use of dry ice in cold rooms can cause increased breathing, headache, dizziness, nausea and visual disturbances due to elevated carbon dioxide concentrations in the air.

Transportation of Cryogens on Campus

Small Volumes

Inside buildings, from room to room, the best transport of liquid nitrogen (4 L and less) is to use a small Dewar which has carrying

Figure 16 Small Dewar

handles and a loose fitting lid or vent. This will allow the gas produced from the liquid boiling off at room temperature to escape. If using a thermos flask, do not screw the lid on, so that evaporating gas may escape safely. These Dewars can be carried by hand.
Never transport an open container of cryogenic liquid, no matter how small.
Anyone transporting Dewars should wear personal protective clothing, including laboratory coats, face mask and insulated gloves.

Larger Volumes

Larger volumes of liquid nitrogen should be transported using 25 liter Dewar and "transport" Dewar (40litre) or 200 liter liquid containers which are on wheels and have pressure relief valves or pressure venting lids.

Figure 17 Larger Volume Dewars

Lifting and carrying full liquid nitrogen containers >25 liter is a two-person task, and should not be carried out alone. The weight of a full 25 liter Dewar is approximately 28 kg. (One liter of liquid nitrogen weighs approximately 0.8 kg). Always use an appropriate wheeled cart to transport a Dewar or storage vessel. Never pull, push or roll a Dewar or storage vessel.

For transport of large cryogenic liquid containers outside, over pavers and walkways a specialized trolley should be used. Stay completely clear of grates, large cracks, and/or uneven portions of the pavement, and any other hazards which could catch a wheel and cause tipping.

Use of Elevators in the Transport of Cryogens

No personnel should accompany a cryogen liquid container or larger Dewar in an elevators or lift. There is asphyxiation risk from boil off in an enclosed space, especially if the elevator breaks down. It is recommended that two people work together to transport liquid nitrogen via the elevator. One person must be stationed on the relevant floor to receive the liquid nitrogen container when the elevator arrives. The second person places the container in the elevator, selects the floor/level and exits the elevator before the doors close. The cryogen must travel unaccompanied. The first person removes the Dewar when it arrives.

First Aid

If skin or eyes comes in contact with a cryogenic liquid, run the area of skin under cool or warm water for fifteen minutes (do not use hot or cold water). DO NOT RUB OR MASSAGE AFFECTED AREAS— this can cause further tissue damage. Refer to MSDS for any specific instructions. Where medical attention is required, ensure to bring along MSDS(s) of chemical(s) to aid medical staff in proper diagnosis and treatment. People suffering from lack of oxygen should be moved to fresh air. If the victim is not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain immediate medical attention. Self-contained breathing apparatus (SCBA) may be required to prevent asphyxiation of rescue personnel. If the eyes are exposed to the extreme cold of the liquid nitrogen or its vapors, immediately warm the frostbite area with warm water not exceeding 40°C and seek immediate medical attention.

Asphyxiation

Nitrogen, Helium and Argon are examples of gases that can reduce or displace the normal oxygen concentration in breathing air. Prolonged breathing of oxygen depleted air can lead to death by asphyxiation (suffocation). Because many of these gases are relatively inert and odorless, their presence in high concentration may not be noticed until the effects of elevated blood carbon dioxide are recognized by the body. The following symptoms appear in situations where asphyxia is possible:

- Rapid and gasping breath
- Rapid fatigue
- Nausea
- Vomiting
- Collapse or inability to move
- Unusual behavior

If you suspect that someone is suffering from asphyxiation, do not enter the affected area alone first call for help. If the victim is unconscious, call Campus Police ext. 911. Remove the victim to the fresh air.

However, if the victim is in a confined space do not attempt to rescue affected person. In confined spaces or where oxygen deficient atmospheres may be present rescue should only be made by those trained in the use of breathing apparatus and confined space entry procedures. The Campus Police should be called in all instances where a trapped person requires rescue.

Laboratory Ventilation and Chemical Fume Hoods

Ventilation is a primary engineering control available to reduce the concentration of gases, dusts, vapors, smoke, and fumes in the air. NFPA Standard 45 states "laboratory work units and laboratory work areas in which hazardous chemicals are being used shall be maintained at an air pressure that is negative relative to the corridors or adjacent non-laboratory areas". This rule helps to prevent the fire, smoke, radiation, and airborne hazardous chemical or infectious microorganisms from spreading outside the laboratory in the event of an accidental release inside the laboratory. Balancing of laboratory ventilation must take into consideration the amount of air exhausted by local ventilation devices such as fume hoods. Windows in modern laboratories cannot be open, as opening of windows tends to pressurize a room, pushing air from the laboratory into adjacent non-laboratory areas.

There are two types of ventilation systems: general and local exhaust ventilation.

General Ventilation

General (dilution) ventilation systems supply clean air that mixes with the air in the workplace, diluting the concentration of the contaminant. General ventilation systems are used primarily to control temperature and humidity, to remove odors, and sometimes to remove traces of toxic substances and microorganisms emitted from carpeting, furniture, and people.

Local Ventilation Devices

General ventilation is not suitable to control exposure to toxic substances because these systems actually spread the contaminant throughout the workplace before exhausting it. Local exhaust ventilation systems remove the contaminant before it spreads through the workplace. Local exhaust ventilation systems capture and discharge air contaminants such as biological, chemical hazardous fumes, and radioactive contaminants.

Common local exhaust ventilation devices found in laboratories include:

- chemical fume hoods
- canopy hoods
- slotted hoods
- biological safety cabinets
- direct connections

Chemical Fume Hoods

Chemical Fume Hoods are one of the primary safety equipment devices in laboratories for handling hazardous chemicals. They are designed to capture, contain and exhaust hazardous fumes generated inside their enclosure. All operations which are liable to produce hazardous or obnoxious concentrations of gas or vapours should be performed in a fume hood. This is to protect your own personal health and safety, as well as for the safety of others in the lab. Detailed information on Fume Hoods can be found within the University of Windsor Fume Hood Policy available at the Chemical Control Centre.

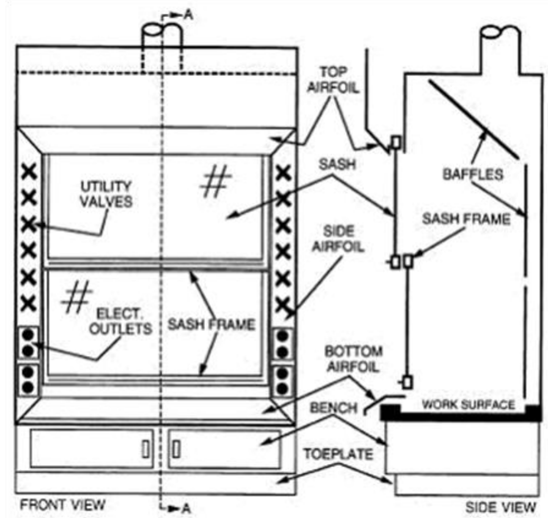


Figure 4 Parts of the Fume Hood

If you have any questions about the capabilities of a particular fume hood or would like to have your fume hood tested contact the Chemical Control Centre : Laboratory Safety, Assurance, and Compliance Group P: 519.253.3000 ext. 3514 F: 519.973.7013 E: ccc@uwindsor.ca www.uwindsor.ca/labsafety
If you would like to report malfunctioning chemical fume hood, please contact the following: Facilities Services Energy Conversion Centre P: 519.253.3000 ext. 7027

Elephant Trunks[6]

Elephant trunks, also known as snorkels or fume collection systems, are a type of local ventilation device. They are large hoses that hang from above a work area and are connected to an exhaust system. The elephant trunks are positioned directly over the laboratory bench tops. They are used when a relatively small volume of noxious fumes are given off by a reaction which does not call for the use of a fume hood. While fume hoods use a directed flow of air to contain fumes, elephant trunks use direct suction. This and the lack of containment, that is provided by a fume hood body, means that elephant trunks can only be effective when they are in close proximity to the vapor source. The maximum distance at which they are effective is the value of the radius of the trunks opening. This is due to entropy, the gases given off by the experiment will expand in volume as they rise and if the trunk is too far away it will not be able to capture all the contaminants. Like other local ventilation systems the rate at which air flows into the mouth of the device is important. The rate of air capture should be set to be between 110 – 150% of the rate of vapor emission, tough this is also dependant on the trunk's opening size.

Figure 5 Elephant Trunks in Essex Hall Undergraduate Lab

Working with Elephant Trunks

- Keep the mouth of the elephant trunk directly over and as close to the source of the fume emissions as is practically possible.
- Do not place any objects between the source of the fume emissions and the mouth of the elephant trunk, especially objects that generate heat.
- Do not reach inside the elephant trunk for any reason.
- Do not use a single elephant trunk for more than one source of emission.
- Do not place fans near an operating trunk as this will disperse the fumes beyond the trunks operational ability.

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[6] Commission on Physical Sciences, Mathematics, and Applications, and Engineering and Physical Sciences. "Laboratory Facilities." *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*. Washington, D.C.: National Academies Press (NAP), 1995. 173. Print.
Industrial Air Solutions. (IAS). (2009). Portable Fume Collectors and Smoke / Dust Collection Systems. Available at: http://www.industrialairsolutions.com/fume-smoke-collectors/portable-fume-collectors.htm. Accessed online 2010.

Canopy Fume Hood

Canopy hoods are designed to vent non-toxic materials such as heat, steam and odors from large or bulky apparatus such as ovens, steam baths, atomic absorption spectrophotometers and autoclaves. They may be wall-mounted or suspended from the ceiling with built-in baffle to increase air velocities and enhance its overall capture efficiency. Coupled with a blower and ductwork, the canopy hood can operate at a wide range of exhaust rates but are usually consider poor substitutes for chemical fume hoods and under no circumstances should be used as a substitute for a chemical fume hood.

Slotted Hoods

Slotted hoods, or benches, have one or more narrow horizontal openings, or slots, at the back of the work surface; the slots are connected to exhaust ducting. These special purpose hoods are used for work with chemicals of low to moderate toxicity only, such as developing black and white photographs.

Biological Safety Cabinets (BSC)

It is essential to distinguish between fume hoods and biological safety cabinets. Biological safety cabinets are enclosures designed for containment of biological hazards. They are equipped with special filters that remove potentially infectious agents such as microbes and spores. The filter does not remove vapors and gases, so BSCs should not be used for chemicals.

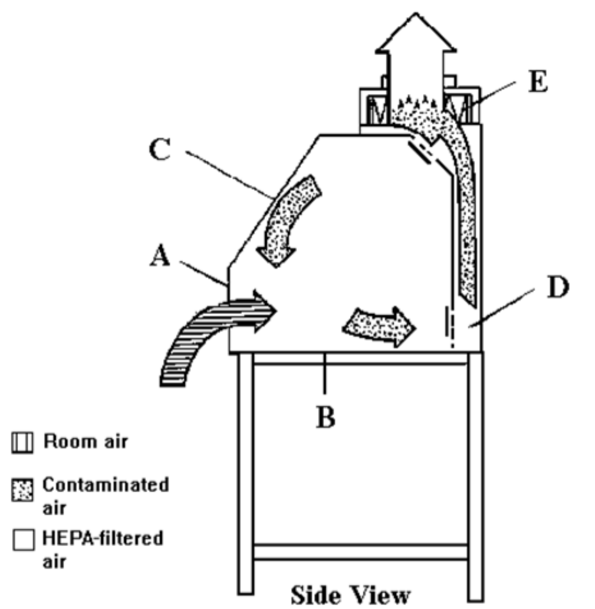

Figure 6 Schematic Diagram of a Biological Safety Cabinet

A biological safety cabinet is a device that makes use of airflow to protect the user, their product and their environment from exposure to biological contamination. It is important to recognize that while biological safety cabinets and fume hoods operate on the same basic principles, they cannot be used interchangeably. Biological safety cabinets are sterile and contain biological hazards with a high efficiency particulate absorbing filters (HEPA).

Types of Biological Safety Cabinets

Though there are different types of biological safety cabinet, they all operate on the same principle and have many of the same parts.

Front opening/Face:	The opening of the biological safety cabinet, or the side where the glove ports are attached on a glove box Figure 6 - Label A.
Work area:	The surface on which the equipment rests and the procedure takes place. Figure 6 - Label B.
Window:	This is equivalent to a sash in the fume hood. It is a glass panel that is used to protect the user while allowing for observation Figure 6 - Label C.
Exhaust plenum:	Where the contaminated air in the cabinet is collected and blown towards the filter before it is vented. Figure 6 - Label D.

HEPA filter: A high efficiency particulate absorbing filter that acts as a sieve to filter microbiological and radioactive contaminants from the air before the air is vented outside the building Figure 6 - Label E.

Biological safety cabinets are rated on their ability to contain harmful organisms. There are three main classes of cabinets (Class I, Class II and Class III). It is important to use the correct cabinet for the work that needs to be done. These can be further subdivided into two categories: A and B. A is a descriptor for cabinets that are not meant to be used with volatile, toxic or radioactive materials, while the B designation has fewer restrictions on the use of these materials. A number placed after the letter indicates the extent to which the hazardous chemicals can be used in the cabinet, a higher number indicates a higher tolerance.

Class I Cabinets

Cabinets that do not have circulated airflow, they are designed to move air away from the user and expel the air into the environment after appropriate filtration. This design protects the user but does not protect the experiment from contamination. These cabinets are to be used when working with low to moderate risk biological agents (Biosafety levels 1-3).

Class II Cabinets

Like Class I cabinets they are designed to protect the user and the environment, but in addition to this they also protect the experiment from contamination. Class II cabinets are to be used when working with low to moderate risk biological agents (Biosafety levels 1-3).
There are several sub categories of Class II cabinets:

<u>Class II, Type A1 Cabinets</u>

These cabinets can either be recirculated into the laboratory or outside the building after appropriate filtration. These cabinets are designed to work effectively regardless of fluctuations in the buildings exhaust system. Class II, type A1 cabinets maintain a positive pressure, a face velocity of 75 fpm and are not suitable for work with volatile toxic chemicals or radionucleotides.

<u>Class II, Type A2 Cabinets</u>

These cabinets make use of the same ventilation systems as Class II, Type A1 cabinets. They are under negative pressure and have a slightly faster face velocity (100 FPM), these differences allow them to be used with minute quantities of toxic/volatile chemicals and trace quantities of radionucleotides.

<u>Class II, Type B1 Cabinets</u>

These cabinets recirculate a small portion of the air within them, they have dedicated ducts and exhaust outside the building after filtration. Type B cabinets maintain negative pressure and the same face velocity as Type A2 cabinets. Class II, Type B1 cabinets are rated for work with low levels of volatile toxic chemicals and trace amounts or radionucleotides.

<u>Class II, Type B2 Cabinets</u>

These cabinets do not recirculate the air within, all of it the air is exhausted outside the building after filtration. It is because of this that they are rated to work with toxic/volatile chemicals and radionucleotides.

Safe Work Practices

Like any piece of laboratory equipment, a biological safety cabinet works best when it is used correctly. Risk of exposure to potentially harmful biological agents can be greatly reduced if a few guidelines are followed. Below is a list of general guidelines to follow when using a biological safety hood.

- Only work with a biological safety cabinet if trained in its use or under the supervision of someone who is trained.
- If the cabinet is equipped with an ultraviolet lamp, the lamp must be turned off before any work is done in the room.
- Don't place personal belongings close to an area where work is being done with potentially dangerous substances/organisms.
- Always take your gloves off when handling personal belongings or leaving the laboratory after working in a biological safety cabinet (dispose of gloves in specially marked biohazard containers).
- The use of equipment that generates heat in biological safety cabinets should be minimized as this interferes with the flow of air and may result in biological agents being expelled into the laboratory.
- Work should be done as deep as possible inside the working area of the cabinet.
- The working area inside the cabinet should only contain objects that are necessary for experiment underway. Clutter will decrease the effectiveness of the cabinet as it blocks airflow and makes accidents more likely.
- Do not block airflow. Raise large objects 5 cm off the counter by placing them on blocks. This allows airflow underneath and prevents stagnant areas.
- A biological safety cabinet is not a substitute for personal protective equipment. Wear gloves, safety glasses, etc. as appropriate.
- Follow manufactures instruction on the proper procedures for cleaning your BSC.

Testing, Maintenance and Regulations

All biological safety cabinets must be tested and maintained to ensure compliance with CSA Z316.3-95; NSF/ANSI 49;

Biological safety cabinets should be tested for base performance evaluation and have their air flow velocity measured when:

- newly installed (includes those that are moved)
- any repair or modifications are made to the fume hood or exhaust system
- once per year

If your BSC has not been tested or you would like to have your BSC serviced or re-tested please contact the Chemical Control Centre at x3523 for more information.

All biological safety cabinets at University are certified by the CCC or an external contractor once per year.

For additional information on BSC visit the University of Windsor's Biological Safety website: www.uwindsor.ca/biosafety

Glove Box

Glove boxes consist of a small chamber with sealed openings fitted with arm-length gloves. The materials are placed inside the chamber and manipulated using the gloves.

Two types of glove boxes exist:

- For work with hazardous substances, such as radioactive materials or infectious disease agents or highly toxic gases - operating under negative pressure.
- For other manipulation of substances that must be contained within a very high purity inert atmosphere, such as argon or nitrogen - operating under positive pressure.

Glove Box Use

Figure 7 Glove Box

- A glove box operating under negative pressure is used when a fume hood might not offer adequate protection. The airflow through the box is relatively low, and the exhaust usually filtered or scrubbed before release into the exhaust system.
- A glove box operating under positive pressure may be used for experiments that require protection from moisture or oxygen. If this type of glove box is to be used with hazardous chemicals, the glove box must be tested for leaks before each use. A pressure gauge should be installed to be able to check the integrity of the system.
- Assemble as much as possible outside of the glove box. The thick gloves in the glove box do not permit a great deal of precision, and therefore can increase the risk of puncture.
- If gloves are punctured and/or contaminated with blood-borne pathogens, they must be replaced.
- The supervisor is responsible for preparation of applicable experimental procedures for glove box works and ensures that all laboratory employees are trained on the use of the glove box.

Biological Hazard

The University of Windsor established, implemented and maintains the Biological Safety Program that is designed to protect the health and safety of students working in laboratories with potential biological hazards. General safety policies and workplace specific procedures have been developed, documented, and implemented.

For detailed information please visit the Biosafety website at: http://www.uwindsor.ca/biosafety.

All work conducted with potentially hazardous biological agents on University premises or under the control of the University is to be performed in accordance with the requirements of the Biological Safety Manual available at www.uwindsor.ca/biosafety . This Manual describes the requirements and procedures established by the University for work with potentially biohazardous infectious materials. It is based upon the Public Health Agency of Canada's Laboratory Biosafety Guidelines (2004 / 3rd edition) and reflects current best practices.

You are urged to use the manual as a road map to compliance within your laboratory. Consult the sections relevant to your research and apply the appropriate safety procedures.

The Biosafety Officer is available at the CCC ext. 3524 for consultation or if you have any question or concern with any aspect of the Biosafety Program at the University.

Radiation Hazard

Radioactive materials include any material that spontaneously emits ionizing radiation. Ionizing radiation is electromagnetic radiation (x-ray and gamma-ray photons) or particulate radiation (beta particles, electrons, positrons, neutrons, and alpha particles) capable of producing ions by direct or secondary processes.

The University of Windsor Radiation Safety Program covers a wide variety of radiation sources, including naturally occurring materials, open and sealed sources, and both laser and x-ray radiation. The operating philosophy of the University is to maintain all radiation exposures As Low As Reasonably Achievable (ALARA).

For detailed information on radiation program visit the Radiation Safety website at: http://www.uwindsor.ca/radiation

University polices and procedures for the safe acquisition, handling, storage, and disposal of radioisotopes can be found within the University's Radiation Safety Manual available at www.uwindsor.ca/radiation. This manual is a key resource for both permit holders and end-users. It includes vital information on a wide range of topics, including: permits; decommissioning labs; and forms and procedures.

For more information on the University of Windsor's Laser or X-Ray Safety Programs, please visit their respective websites: www.uwindsor.ca/x-ray and www.uwindsor.ca/laser .

The Radiation Safety Officer is available at the CCC ext. 3524 for consultation or if you have any question or concern with any aspect of the Radiation Safety Program at the University.

Chemical Hazards

EVERY chemical is hazardous, even water; it depends on dose. We handle hazardous chemicals in our every day lives, from pumping gasoline to using chlorine bleach. The keys to the safe use of these and any chemical is to understand hazards presented by each specific chemical and knowing, and using the appropriate precautionary measures to minimize these hazards.

The degree of hazard presented by a substance depends on: [7]

- Chemical properties e.g. flammability, corrosivity, solubility
- Physical properties e.g. volatility, density
- Biological properties e.g. viability, pathanogenicity, infectivity
- Physical state e.g. solid, liquid, gas, aerosol
- Toxicity e.g. carcinogenetic, neurotoxicity
- Amount of exposure
- Duration of exposure
- Route(s) of entry e.g. inhalation, skin absorption, injection
- Interactions with other substances
- Manner in which substance is handled
- Susceptibility of individual(s) exposed e.g. unborn fetus

To obtain information on all relevant properties of a substance in order to recognize and evaluate its hazards make use of labels, material safety data sheets and information on reactive chemical hazards.

"Universal Precautions" are generally accepted standards for dealing with potentially infected materials. They cover personal protection, handling techniques and waste disposal.

Biohazardous infectious material is covered under the University Biological Safety Program and the safety practices and procedures are detailed in the Biological Safety Manual. Please visit the Biosafety website at: www.uwindsor.ca/biosafety

List of high toxicity chemicals can be found at: http://msds.chem.ox.ac.uk/hightoxicity.html

All working with toxic or poisonous chemicals must be aware of their specific hazards.

Exposure Routes

Effects of exposure to chemicals can be immediate or delayed, reversible or irreversible, local or systemic. Chemicals can enter the body through the following routes:

- ***Inhalation***
  Inhalation is absorption through the respiratory tract by inhalation. This is probably the easiest way for chemicals to enter the body.
- ***Ingestion***
  Ingestion is absorption through the digestive tract by eating or smoking with contaminated hands in contaminated work areas. Depending on particle or droplet size, aerosols may also be ingested.

[7] G. Shematek, W. Wood Laboratory Safety, CSMLS Guidelines 6 Edition 2006

- ***Skin or Eye Contact***
  This is absorption through the skin or eyes. Skin contact is the most common cause of the widespread occupation disease dermatitis. The eyes are very porous and can easily absorb toxic vapors that cause permanent eye damage.
- ***Injection***
  Injection through the skin. This can occur through the misuse of sharp items, broken glass, or hypodermic needles

Precautions - General Guidelines

Before laboratory workers / students may begin work with **highly toxic chemicals** they must be trained on the laboratory specific Standard Operating Procedure (SOP) for these materials by the Principal Investigator or laboratory supervisor. The MSDS is a good source for safety information, handling and emergency measures for chemicals.

In particular SOPs should be prepared for the use of each chemical carcinogen or suspect carcinogen. All laboratory workers should be trained in these procedures and routinely follow them. Also, prior approval from the laboratory supervisor for use may be required.

Chemical Storage

Proper storage of chemicals in the laboratory is extremely important in order to maximize personal safety. Proper chemical storage is designed to protect flammables from ignition, minimize the potential of exposure to poisons and segregate incompatible compounds to prevent their accidental mixing (via spills, residues, fires or human error).

Shelves used for chemical storage should be equipped with edge guards to prevent containers from protruding over or sliding off the edge, they should be securely fastened to the wall or floor to provide added stability. Only sturdy shelves should be used and load capacities must exceed that of the chemicals stored on them. Wooden shelving should not be used for chemical storage. Ensure chemicals are stored within easy reach of everyone in the laboratory. Store frequently used items between knee and shoulder height. Liquid or corrosive chemicals should never be stored on shelves above eye-level. Store heavy objects on lower shelves and large bottles and containers as close to floor level as possible.

General Rules of Safe Chemical Storage – Code of Practice

- Chemicals should not be routinely stored on the benchtops. In such locations they are unprotected from exposure and participation in a fire situation and are also more readily knocked over. Each chemical should have a specific storage area and be returned there after use.
- Ensure that lighting and ventilation is adequate in the storage area but chemicals are store away from direct sunlight or sources of heat. Refer to the Material Safety Data Sheet for storage directions.
- Do not store incompatible chemicals together. Chemicals must be stored by hazard category and not alphabetically (except within a hazard group). If a chemical presents more than one hazard, segregate according to the primary hazard.
- Store acid and bases on low shelf areas or in acid cabinets and ensure that **acids are physically separated from bases**.
- Store volatile toxic and odorous chemicals in a way that prevents release of vapours inside closed secondary containers, ventilated cabinets and /or apply paraffin sealing.
- Store flammables requiring refrigeration in explosion-safe or lab-safe refrigerators.
- It is good laboratory practice to store dangerous substances labeled toxic / highly toxic (includes substances that are carcinogenic / mutagenic / toxic to reproduction) in a locked cupboard with the appropriate hazard sign. All carcinogens, mutagens, and teratogens stored on shelves or in refrigerators in the work or storage area must be placed in properly labeled, unbreakable containers. All containers must be properly labeled.
- Oxidizing substances should be stored in a metal cabinet and away from organic matter such as wood and paper. Oxidizing agents must also never be stored with flammable solvents, since fires and explosions can result after any spillage, even without a naked flame or heat.
- Dangerous drugs and medicines should be stored in a locked cupboard. If it is necessary to store them at low temperatures the fridge or freezer used should be fitted with a lock.
- Label reactive or unstable chemicals (e.g., ethers) with the date of receipt and the date opened.
- Minimize the number of chemicals and size of containers stored in the lab. For commonly used chemicals (i.e. acids, solvents), keep quantities in the laboratory to a one-week supply.
- Store containers of liquids inside secondary containers (such as trays or tubs) that are large enough to hold spills.

- Do not store chemical containers directly on the floor where they might be knocked over and broken, unless they are in ULC approved safety cans or still in their original shipping carton and packing.
- Do not store chemical containers on top of flammable storage or acid storage cabinets, unless they are empty.
- Regularly inspect chemicals in storage to ensure there are no leaking or deteriorating containers.

- Purchase solvents in containers with a plastic safety coating, where possible or recommended.
- Dispose of unwanted chemicals promptly.
- Keep inventory records of chemic
- Fume hoods should not be used as general storage areas for chemicals. This may seriously impair the ventilating capacity of the hood.
- The quantities of chemicals that are stored within a laboratory should be minimized, as specified by NFPA 45.

Flammable Liquid Storage Cabinets

Flammable and combustible liquids should be stored only in approved flammable-liquid storage cabinets, not in a fume hood, out on the benches, or in a non-approved storage cabinet. A maximum of 3 flammable cabinets are allowed per laboratory**. Up to 250L of flammable liquids, in closed containers can be stored in a metal cabinet. Up to 750L of Class 1 liquids may be stored in a group of cabinets in a single laboratory/fire compartment. Each metal cabinet must be 30 meters apart.**

Figure 8 Flammable Cabinet

Only those flammables in use for the day should be outside the cabinet. Guidelines for cabinet use include:

- Use NFPA or ULC approved flammable liquid storage cabinets.
- Keep cabinet doors of the cabinet closed and latched.
- Do not store other materials in these cabinets such as oxidizers.

Ventilation is prudent when the liquids stored in the cabinet are highly toxic or extremely odoriferous. Particularly odoriferous substances such as mercaptans have such a low odor threshold that even with meticulous housekeeping the odors persist; hence, ventilation may be desired.

If a ventilated flammable-liquid storage cabinet is used under a fume hood, it should not be vented into the fume hood above it. It should have a separate exhaust duct connected to the exhaust system. Fires occur most frequently in fume hoods. Fire from a fume hood may propagate into a flammable-liquid storage cabinet directly vented into the hood.

Chemical Compatibility and Simplified Segregation Scheme

Compatible chemicals have similar hazards. Chemicals with similar hazards, if mixed together, produce either a mild reaction or none at all. However, incompatible chemicals that have dissimilar attributes should be stored separately to avoid violent reactions. ***Do not simply store chemicals in alphabetical order*.**

Compatible chemical storage is a complex and demanding task that is impacted by regulations, chemical properties, storage conditions, and chemical reactivity. It may be uncomplicated to prepare a compatible chemical storage scheme for small, simple application. Larger storage applications require a more complex approach that includes individually evaluating each chemical for its proper storage condition.

What should be *required as a minimum for research lab,* however, is to establish and separate chemicals according to similar hazards, such as flammability, corrosively, sensitivity to water or air, and toxicity. The following major categories of chemicals as shown in the table below are recommended:

Table 6 Major Categories of Chemicals ***Adopted from McGill University Laboratory Safety Manual (used with permission)***

FLAMMABLES	NON-FLAMMABLE SOLVENTS	ACIDS
• Store in grounded flammable liquid storage cabinets • Separate from oxidizing materials	• Store in a cabinet • Can be stored with flammable liquids • Separate from oxidizing materials	• Store in a cabinet of non-combustible material • Separate oxidizing acids from organic acids • Separate from caustics, cyanides, sulfides
Examples: acetone, ethanol, glacial acetic acid	*Examples:* mineral oil, carbon tetrachloride, ethylene glycol	*Examples:* nitric acid, hydrochloric acid, sulfuric acid
CAUSTICS • Store in a dry area • Separate from acids	**WATER REACTIVE CHEMICALS** • Store in cool, dry location • Separate from aqueous solutions • Store away from plumbing fixtures	**OXIDIZERS** • Store in cabinet of non-combustible material, away from reducing agents • Separate from flammable and combustible materials
Examples: ammonium hydroxide, sodium hydroxide, potassium hydroxide	*Examples: s*odium, potassium, lithium	*Examples:* sodium hypochlorite, benzoyl peroxide, sodium nitrite, bromine, nitric acid
NON-OXIDIZING COMPRESSED GAS • Store in well ventilated area • Separate physically form oxidizing gases	**OXIDIZING COMPRESSED GASES** • Separate physically from compressed gases	**NON-VOLATILE, NON-REACTIVE SOLIDS** • Store in cabinets or open shelves with edge guards
Examples: nitrogen, hydrogen, carbon dioxide **Link to Chemical Storage**	*Examples:* oxygen, chlorine, nitrous oxide	*Examples:* agar, sodium chloride, sodium bicarbonate

One problem with the implementation of this type of system of assigning chemicals to a specific storage area based on chemical hazards is the actual identification of the hazards themselves.
This can be done by referring to:

- the label which furnishes a quick method of determining whether the material is a fire hazard, health hazard, or reactivity hazard.
- the reactivity section of the Material Safety Data Sheet (MSDS).
- reference manual on reactive chemical hazards.

The storage scheme outlined above should be considered as a preliminary segregation. Certain hazardous combinations can occur even between chemicals within any given category. *For example, a common mistake observed in research laboratories is to store glacial acetic acid, a flammable liquid with a flash point of 39 ^{0}C, along with the acids, when it should be stored as a flammable liquid.*

The next step is to establish the reactivity of each chemical to verify its compatibility with all others in the same category. This can be done by using reference manuals on reactive chemical hazards which list for each chemical the names or classes of chemicals with which it produces a hazardous reaction. Table 6 shows common examples of incompatible combinations for some commonly used chemical.

Explosive chemicals

An explosive chemical may be defined as a material that, when exposed to some type of initiation, undergoes a sudden, violent change, releasing excessive energy. Initiators include heat, shock, friction, light, and contamination from non-compatible material. Some chemicals become increasingly shock sensitive with age. When initiated these chemicals undergoes rapid chemical change, evolving large volumes of highly heated gases that exert pressure on the surrounding medium. The term applies to materials that either detonate or deflagrate.

Figure 9 The Explosive Addition of $Alcl_3$ to Water

Heat, light, mechanical shock, and certain catalysts initiate explosive reactions. Hydrogen and chlorine react explosively in the presence of light. Acids, bases, and other substances catalyze the explosive polymerization of acrolein, and many metal ions can catalyze the violent decomposition of hydrogen peroxide. Shock-sensitive materials include acetylides, azides, nitrogen triiodide, organic nitrates, nitro compounds, perchlorate salts (especially those of heavy metals such as ruthenium and osmium), many organic peroxides, and compounds containing diazo, halamine, nitroso, and ozonide functional groups. Some are set off by the action of a metal spatula on the solid; some are so sensitive that they are set off by the action of their own crystal formation. Diazomethane (CH_2N_2) and organic azides, for example, may decompose explosively when exposed to a ground glass joint. Picric acid becomes shock sensitive and explosive if it dries out. Establish if a chemical is explosive. Refer to the label and the Material Safety Data Sheet.Write the dates received and opened on all containers of explosive or shock-sensitive chemicals and inspect all such containers every month. Always keep picric acid solutions wet i.e., 30% or more water Discard opened containers after six months, and closed containers after one year, unless the material contains stabilizers. Perform experiments behind face shield and using appropriate personal protective equipment and work with small quantities.

In case of a discovery of an explosive or unstable chemical contact the Chemical Control Centre (ext. 3524) or Campus Police by dialing 911 from a campus phone.

Materials Liable to Form Peroxides in Storage

Organic peroxides are among the most hazardous substances handled in the chemical laboratory. They are generally low-power explosives that are sensitive to shock, sparks, or other accidental ignition. They are far more shock-sensitive than most primary explosives such as TNT. A peroxide-containing material always constitutes an explosion risk, but the risk is particularly serious if the material is heated. This is because peroxides are generally less volatile than the compound from which they are formed. Distillation therefore leads to progressive concentration of the peroxide. The combination of a concentrated solution of peroxide with heating can result in explosive decomposition.

Also potentially hazardous are compounds that undergo auto-oxidation to form organic hydroperoxides and/or peroxides when exposed to the oxygen in air. Especially dangerous are ether bottles that have evaporated to dryness. Peroxide present as a contaminant in a reagent or solvent can be very hazardous and change the course of a planned reaction. Autoxidation of organic materials (solvents and other liquids are most frequently of primary concern) proceeds by a free-radical chain mechanism. For the substrate R—H, the chain is initiated by ultraviolet light, by the presence of a radical source, and by the peroxide itself. Oxygen adds to the R radical, producing the peroxy radical R—O—O. The chain is propagated when the peroxy radical abstracts a hydrogen atom from R—H. Excluding oxygen by storing potential peroxide-formers under an inert atmosphere (N_2 or argon) or under vacuum greatly increases their safe storage lifetime. In some cases, stabilizers or inhibitors (free-radical scavengers that terminate the chain reaction) have been added to the liquid to extend its storage lifetime. Because distillation of the stabilized liquid will remove the stabilizer, the distillate must be stored with care and monitored for peroxide formation.

For a list of materials that may form peroxides see appendix 2

WARNING: If a "peroxidizable" compound is discolored or contains either a distinct layer or suspect crystals it should be treated as a potential explosive.

If this is the case the most prudent action is to **NOT TOUCH OR MOVE THE SUSPECT CHEMICAL**. Alert your immediate supervisor to the potential problem. Your supervisor should contact the Chemical Control Centre - Environmental Protection Services (ext.3519) to make arrangements for disposal.

General Guidelines for Storing Peroxide Forming Chemicals

- Identify all peroxide forming chemicals in your inventory. Write the opening date and discard date on the containers of chemicals that may degrade to become potentially explosive (refer to the MSDS or container label).
- Store in airtight containers in a dark, cool, and dry place.
- Never store peroxide formers in a freezer because a change from a solid to a liquid can cause detonation.
- Discard or test peroxide forming chemicals before the expiration date printed on the container label. Contact the CCC for disposal information.
- Inspect peroxide-forming chemicals often for evidence of contamination, degradation, or any change from normal physical or chemical characteristics. Contact the CCC immediately if you suspect a material may have become explosive. Post warning signs so others do not handle or disturb the material.
- If precipitate appears in an organic chemical that may form an explosive peroxide (crystals around the neck or cap of bottle), or if an oily layer appears, do not move it. Contact the CCC immediately.
- Once a container is opened, the chemical should be tested for peroxides not less frequently than once every six months using peroxides test strips.
- **Never test containers of unknown age or origin. Old bottles are likely to contain concentrated peroxides, and peroxides may have crystallized in the cap threads, which can present a serious hazard when the bottle is opened for testing.** Contact the CCC ext.3523 for help with managing older containers.

For more information on peroxides see the University of Windsor's Laboratory Safety Bulletin (LSB) 2008-01 which is available at www.uwindsor.ca/labsafety and Section: Oxidizing Chemicals of this Manual.

Explosive Boiling

Not all explosions result from chemical reactions. A dangerous, physically caused explosion can occur if a hot liquid or a collection of very hot particles comes into sudden contact with a lower-boiling-point material. Sudden boiling eruptions occur when a nucleating agent (e.g., charcoal, ''boiling chips") is added to a liquid heated above its boiling point. Even if the material does not explode directly, the sudden formation of a mass of explosive or flammable vapor can be very dangerous.

Chemicals Spills[8]

Anticipate spills by having the appropriate clean up equipment on hand. The appropriate clean up supplies can be determined by consulting the MSDS. These following guidelines should be applied when initially responding to a spill situation:

Figure 10 Spill

- Determine appropriate clean up method by referring to the Material Safety Data Sheet. If you are unsure how to proceed, or if you do not have the necessary protective equipment, do not attempt to clean up the spill.
- If the spill is minor and of known limited danger, clean up immediately following guidelines listed below.
- If the spill is of unknown composition, or potentially dangerous (explosive, toxic vapours), alert everyone present and evacuate the room.
- If the spill cannot be safely handled using the equipment and personnel present, call the Campus Police emergency telephone number (**ext. 911)** to request assistance.

TRAINING INFORMATION
Visit www.uwindsor.ca/labsafety and take the Spill Response Training. The presentation explains your role during spill response and provides guidelines to follow in case of minor or major spill.

Controlling and Cleaning a Chemical Spill

In the case of a chemical spill follow these steps:

- **Treat Injured People First:**
  Providing first aid to injured people takes priority over cleaning a hazardous materials spill. Inform emergency personnel that the spill involves hazardous materials.
- **Alert everyone in the Area:**
  Inform everyone within the vicinity of the spill that an accident involving hazardous materials has occurred. Mark the spill zone and post appropriate signage (if needed) to reduce the potential for further contamination.
- **Control Contamination:**
  Take action to prevent the spread of hazardous materials.
- **Clear Area:**
  Remove all unnecessary individuals from the area of the spill. Attempt to reduce the movement of people within the spill zone. Follow procedures listed below.
- **Summon Aid:**
  If you are unsure of how to clean the spill, contact the Chemical Control Centre (ext. 3519).
- **Report Incident:**
  Once area has been cleaned and no further hazard exists, complete a chemical spill report.

[8] Chemical Control Centre, University of Windsor Spill Response Manual, 2009

Spill Types and Cleaning Procedure

Gas Leak

If the leak cannot be shut off, the cylinder should be placed in or adjacent to a fume hood and left to bleed off.

- If the leak is in the valve assembly, a plastic bag can be fastened over the head of the cylinder which can then be taken to a fume hood or outside.

Liquid Spill (excluding Mercury)

- Encircle the liquid with the Universal Gel Absorbent (located in Spill Kit).
- Cover up the spill with the Universal Gel Absorbent .
- Let the Gel Absorbent sit until it hardens and the liquid is absorbed (if needed, add more absorbent).
- Once the absorbent has hardened, use scrap and pan to pick up the gel and place into a plastic bag.
- Label bag to the spill type.
- Rinse and decontaminate utensils and area.
- Send bag of gel material to the Chemical Control Centre for proper disposal.

Mercury Spill

- Encircle the liquid with the mercury (Hg) Absorbent (located in Spill Kit).
- Cover up the spill with Hg Absorbent.
- Dampen powder with water (mercury will react with powder forming a metal/mercury amalgam).
- Let the Absorbent sit until it hardens (if needed, add more absorbent) .
- Once the amalgam is completed, sweep and pan to pick up the amalgam and place into a plastic bag.
- Label bag 'Contaminated Mercury'.
- Rinse and decontaminate utensils and area.
- Send bag to the Chemical Control Centre for proper disposal.

Solid (Powder) Spills

- Encircle the powder with sand or vermiculite.
- Cover up the powder with the above material .
- Sweep and pan up the mixture and place into a plastic bag.
- Label bag as to what type of chemical it is.
- Rinse and decontaminate utensils and area.
- Send bag of mixture to the Chemical Control Centre for proper disposal.

It is not within the scope of this manual to list procedures for all possible spill categories of chemicals. For further information on responses to other categories consult the **University of Windsor Hazardous Materials Spill Response Manual at www.uwindsor.ca/ccc.**

Hazardous Waste Disposal

Laboratory **hazardous** waste can be broken down into the following categories:

- Chemical
- Biohazardous
- Radioactive

Waste minimization

All laboratory personnel are requested to minimize the amount of hazardous waste collected for disposal. In many cases the purchasing of excessive quantities of laboratory reagents to benefit from quantity discounts should be avoided. The costs of disposal of these reagents may far exceed any savings realized at the time of purchase. Usually there is no need to store excessive quantities of chemicals, as orders are generally delivered the day after an order is received. Many companies occasionally clear their stock of unwanted reagents by donating them to laboratories, which eventually transfers the cost of disposal to the University. Do not accept donations of materials that you don't plan to use. Attempts should be made to find potential users for reagents that are not needed.

Hazardous Waste Disposal Guidelines

For all specific guidelines regarding chemical waste consult the Hazardous Materials Disposal Guide, prepared by the CCC.
The guide can be found at http://www.uwindsor.ca/ccc.

General Guidelines

- Avoid accumulation of hazardous materials in laboratory areas by disposing of waste frequently.
- Use safe practices for identification, handling and storage of the materials that are designated as waste.
- Become familiar with the University of Windsor requirements for labelling and packaging wastes and be aware that these requirements change in response to new regulations.
- Avoid mixing wastes of different categories unless instructed to do so by the Hazardous Material Technician from the Chemical Control Centre (CCC).
- Avoid mixing concentrated solutions of wastes to avoid dangerous reactions.
- It is illegal to discharge wastes into the sewer or regular garbage.
- Participate in recycling programs where available.

General Requirements Related to Packaging Waste[9]

The Chemical Control Centre requires that its clients follow specific guidelines related to the packaging of hazardous waste, including:

- All materials must be collected in an appropriate waste storage container. The Centre provides free of charge a wide variety of approved containers for the collection, storage, and transportation of hazardous waste.
- Each container must be labeled appropriately to reduce the possibility of the downstream mixture of incompatible materials.

[9] Hazardous Materials Disposal Guide, Chemical Control Centre, University of Windsor, 2007

- Secondary containment must be used during the transportation of materials to prevent leakage should breakage occur. Examples include a cart with a lip, rubber bucket, or fiber box.
- Incompatible and highly reactive chemicals must always be packaged separately to minimize fire and explosion hazards in case of accidental breakage.
- Chemical, biohazardous and radioactive wastes are handled differently and cannot be stored together for that reason each waste container should have only one type of waste material inside.

Hazardous Waste Labels

Hazardous waste labels are used to communicate the contents of all waste containers to laboratory researchers, facilities services, and chemical handling staff. Pre-printed labels are available free of charge from the CCC and are typically attached to the waste container. Also, labels are available online at www.uwindsor.ca/ccc.

Attach a "Hazardous Waste Label" to the container as soon as it is used for the collection of hazardous waste. Record the starting date on the label.

Acceptable Alternatives

In addition to pre-printed "Hazardous Waste Labels" (as seen above), the Chemical Control Centre accepts hazardous waste materials, which have an alternative notification label. Acceptable labels include WHIMS labels, University of Windsor workplace labels, and/or the original supplier label.

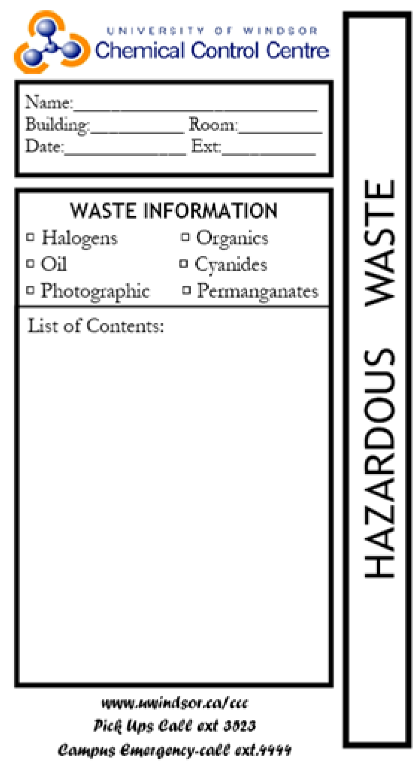

Figure 18 UWin Waste Label

Disposal of Chemical Waste

- Collect chemical waste into the designated waste containers such as 2.5 L plastic coated bottle or 20 L plastic drum.
- Collect inorganic substances separately (containers are available free of charge from the CCC) and do not mix solids with liquids.
- As ingredients are added to the container, on the label record the chemical name and amounts added under the "List of Contents".
- Containers in the process of being filled must be kept closed and stored in a safe location. Storage location should be selected based on the characteristics of the contents.
- When bottle is full (up to the black line) make sure it is capped.
- Incompatible and highly reactive chemicals must be packaged separately to minimize fire and explosion hazards**.**

Departmental Procedures and Pick Up Locations of Waste

- **Essex Hall**: Please bring waste material directly to the Chemical Control Centre (Essex Hall room B-37).
- **Biological Sciences:** Please deliver material to Biological Stockroom (Biological Sciences room 316). These materials will be picked up directly from the stockroom's chemical vault.
- **Visual Arts:** Please contact the Centre directly to arrange the pick-up of photographic wastes.
- **GLIER**: Please call the CCC to make arrangements for pick-up of hazardous waste.
- **Memorial Hall:** Please call the CCC to make arrangements for pick-up of hazardous waste.

Unknown Chemical Waste

As a service to you, the CCC will take all of your waste, even unknowns. For everyone's safety please make every effort to identify all waste before submitting for disposal.

For unknown chemical waste provide name of research group, telephone number, type of research, storage method, approximate age of container, and all relevant information (i.e. organic, acid, air reactive, pH, oxidizer etc). This information may greatly reduce the hazards involved in handling and testing the material.

Biohazardous Waste

Hazardous biological materials include biotoxins and biomaterials capable of infecting or causing harm to persons, animals or plants. The University of Windsor's Biological Safety Program (http://www.uwindsor.ca/biosafety) outlines the policies and procedures related to the disposal of hazardous biological waste, including incineration and steam sterilization requirements.

Biomedical Waste

Biomedical waste at University includes the following:

- Animal anatomical waste (carcasses, body parts, organs)
- Human anatomical waste
- Non-anatomical waste, which consists of :
    - Sharps which have contacted animal or human blood, biological fluids or tissues.
    - Containers with medical first aid waste.

The destruction of biomedical animal waste is done by way of incineration by external companies. Materials to be sent out for disposal are placed in the appropriate container, the container is labelled, and then the waste is stored in a designated, refrigerated disposal area in the CCC pending collection by the disposal firm.

Non-anatomical waste is decontaminated internally by the CCC, by way of autoclaving.

Sharps Disposal

Sharps are defined as any material that can penetrate plastic bags: examples include syringe needles, scalpel blades, glass and plastic pipettes, disposable pipette tips, etc.
DO NOT place SHARPS into regular garbage or into the "GLASS ONLY" pail.
For disposal purposes, sharps are categorized as following:

1. **Uncontaminated**
2. **Biohazardous**
3. **Chemically contaminated**
4. **Radioactive**

Dispose of sharps in an appropriate sharps container; **never in a waste bin or plastic bag**. Dispose of sharps immediately after use - not later - to avoid injuries. See the following sections for instructions on proper labeling and disposal of each type of contaminated sharp.

Laboratory glass

Broken laboratory glass and Pasteur pipettes not used for biological materials are not considered “sharps” for disposal purposes.

Figure 19 Container for Broken Glass

- They must be placed in yellow bin labeled “Broken Glass Only” for recycling. Broken glass cannot be placed into regular garbage pails.
- And vice-versa, no garbage goes into the "Broken Glass Only" pails; inevitably someone gets cut picking out the garbage!
- Make sure glassware is rinsed clean of chemicals before adding to the glass only pail.
- When this pail gets full - place a notice on it to let the custodians know that you would like it to be emptied.
- Biohazardous broken glass must be collected into 5- gallon yellow pail (item USG 0262 from the CCC) and treated in autoclave to decontaminate prior to disposal.

Sharps containers


Figure 20 Sharps Disposal Container

An approved sharps disposal container can be purchased from the CCC at a modest cost. These containers are closable, puncture resistant and leak-proof and available in 2.25 L (LAB0618), and 13.2 L (LAB0617). Sharps disposal containers must be easily accessible to laboratory personnel and located as close as feasible to the area where sharps are used.

Disposing of uncontaminated sharps

Uncontaminated sharps are free of biohazardous, chemical and radioactive contamination**.**

- Use a puncture-proof container provided from the CCC, label with the word "UNCONTAMINATED SHARPS". Accumulate sharps in this container, without overfilling.
- When full, close and seal the container and place it beside the regular garbage receptacle for pickup by the housekeeping staff.

Disposing of biohazardous sharps

Figure 21 Biohazardous Sharp Container

Figure 22 UWin Treated Biological Material Label

- Collect contaminated sharps in a plastic, puncture proof sharp container (available from the CCC) with the word "BIOHAZARDOUS SHARPS" or other appropriate hazard warning symbol and the name of the Principal Investigator.
- Must be sterilized to render the waste nonhazardous before disposal. Autoclaves the container first, then appropriately labels as "non-hazardous" with the label "TREATED BIOLOGICAL MATERIALS" and dispose of as regular waste.

Disposing of chemically contaminated sharps

Chemically contaminated sharps are sharps contaminated with hazardous chemicals only.

- Place chemically contaminated sharps in a sharps container available from the CCC. Deface or remove any existing biohazard labels.
- Label container with the hazardous chemical contaminants using proper chemical names.
- Before chemically contaminated sharps containers are full, tightly lid them or tape closed. Manage chemically contaminated sharps as unwanted hazardous chemicals by bringing them for disposal to the CCC.

Disposing of radioactive sharps

- Radioactive sharps are sharps that are contaminated with radioactive materials only.
- All sharps must be placed in a puncture resistant sharps container which is available from the CCC.
- Place either a sticker or label to the exterior stating "Caution Radioactive Materials".
- Completely fill-out and attach the Radioactive Waste Tracking Record to the exterior of the container.
- Call the CCC to schedule a pick-up (ext.3519). When calling, please inform the customer service representative that you require pick-up of a radioactive sharps container.

Safe Disposal of Empty Chemical Containers

Empty chemical containers can contain residual amounts of chemicals. In an effort to ensure that this residue is handled properly and to be able to properly dispose of these containers, the following procedure has been developed.

Figure 23 Empty Bottles for Disposal

Once a chemical container is empty it must meet the following criteria for safe disposal:

1. Container must be free of any chemical's residue.
2. Original label must be covered or defaced.
3. Item must be removed from a laboratory's inventory within Hazardous Material Information System (HMIS).

Preparing empty containers for disposal

If the content is WATER SOLUBLE:

- Rinse the empty container with water, collect the initial concentrated rinse and discard to the proper liquid waste container.
- Ensure the bottle is dry, the label has been defaced or removed and the chemical removed from inventory (see below).
- If glass container, place in the yellow broken glass container found in your lab.
- If plastic container, place in regular trash.

If the content is TOXIC:

- **For containers holding chemicals that are highly toxic, pyrophoric, water reactive, and/or if the chemical residue cannot be rinsed out dispose of the entire container as hazardous chemical waste by bringing it to the Chemical Control Centre or authorized satellite waste storage location (i.e. GLIER, Biology, etc.).**
- For containers holding non-reactive chemicals, **triple rinse** with water or other suitable solvent. Collect all 3 rinses and discard to proper liquid waste container.
- Remove lid and place bottle in fume hood until all liquid has evaporated.
- Ensure the bottle is dry, the label has been defaced or removed and the chemical removed from inventory (see below).
- If glass container, place in the yellow broken glass container found in your lab.
- If plastic container, place in regular trash.

If the content is a SOLVENT:

- If the content is a solvent such as volatile organic solvents (e.g. acetone, hexane, methylene chloride etc.) leave the container with the lid removed to air–dry in the fume hood.
- Ensure the bottle is dry, the label has been defaced or removed and the chemical removed from inventory (see below).
- Place the bottle in the yellow broken glass container found in your lab.

Defacing labels

To deface a label use a good marker and insure all hazards warning information is not visible and "EMPTY" is clearly written on the container.

Removing chemicals from the inventory

Please make every effort to remove the chemical from the Hazardous Material Information System (HMIS) inventory:

1. Peel off the yellow inventory label with six-digit chemical's serial number and attached to "REQUEST FOR REMOVAL OF CHEMICALS FROM HMIS" form (CCC-2010-001- available from the CCC) or write down serial number and submit completed form to the Chemical Control Centre for processing.
2. Alternatively, you could remove chemicals from laboratory inventory by accessing the HMIS at www.uwindsor.ca/hmis. Find the items within HMIS by entering its serial number and mark the chemical as disposed.

Figure 24 CCC Yellow Inventory Label

Radioactive Waste

The disposal of radioactive waste (liquid scintillation vials, solids, liquids, etc.) is regulated by the Canadian Nuclear Safety Commission (CNSC). The University of Windsor's Radiation Safety Program outlines the specific policies and procedures related to the disposal of radioactive waste on campus.

- Use approved "radioactive "waste containers, provided free of charge from the CCC.
- Principal Investigators and/or Departments are responsible for arranging disposal by the CCC.

Please refer to the University of Windsor's Radiation Safety Program for more information regarding radioactive waste visit http://www.uwindsor.ca/radiation

Glassware Safety

Accidents involving the improper use of glassware are one of the leading causes of laboratory accidents. Glassware should always be handled with extra care. Safe laboratory practices can greatly reduce the risk of accidents and injuries. Listed below are general safety guidelines to follow when using glassware.

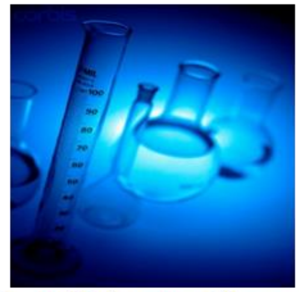

Figure 1 Laboratory Glassware

- Borosilicate glassware is recommended for all laboratory glassware except for special applications that use Pyrex, shatterproof glassware.
- Never use cracked or chipped glassware. Check each piece of glassware for hairline or star cracks before using it.
- When working with glass, do not use unnecessary force, be firm but gentle.
- Hot glass looks the same as cold glass. Handle hot glassware with appropriate hand protection or tongs. Heated glass will remain hot for a long time. Do not immerse hot glassware into cold water, it may shatter.
- Keep glassware away from the edge of the bench top.
- Tape permanent vacuum glassware which presents an implosion risk with either electrical or duct tape or use appropriate shielding.
- Wear appropriate hand protection (thick gloves) and eye protection when picking up broken glass. Use a brush and dustpan to sweep up the broken glass.
- Proper instruction should be provided in the use of glass equipment designed for specialized tasks, which can represent unusual risks for the first-time user.
- Many commercial glass cleaners are available. Follow the manufacturer's directions for the use of these products since some are corrosive and can damage the glass. Organic solvents are acceptable cleaning agents when conditions warrant their use.
- When cleaning laboratory glassware, be sure to wear appropriate gloves that have been checked for tears or holes. Keep cleanup area tidy and do not pile up glassware as this may lead to breakage.
- Dispose of broken glass in properly labeled plastic or metal containers, which are not used for other garbage. Or use a commercially available disposable glass disposal container.
- Do not use glassware when working with hydrofluoric acid, hot phosphoric, or strong hot alkalis.

Figure 19 Container for Broken Glass

Ground-Glass Surfaces

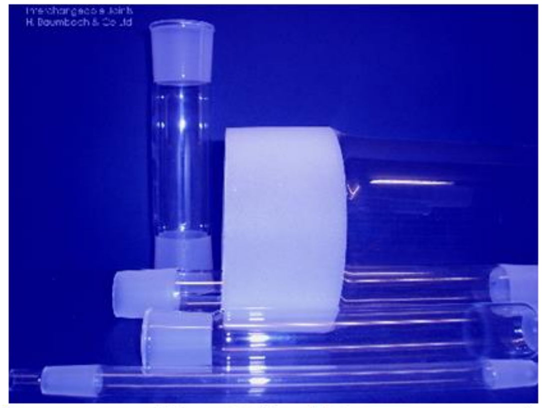

Figure 2 Glass Joints

- Ground-glass joints and stopcocks should never be used when dry. Although ground-glass surfaces seal well without the use of lubricants, it is advisable to lubricate them to prevent sticking and breakage.
- Ground surfaces must be cleaned prior to lubrication – dust, dirt and particulate matter may score the surface and cause leakage.
- Different lubricants are used for various operating conditions:
  - Silicone grease – for high temperature and high vacuum.
  - Glycerin – for long term reflux or extraction.
  - Hydrocarbon grease – for general laboratory use.
- Alternatively, Teflon sleeves can be used for this purpose.
- Lubricate joints that must be airtight and when glassware contains strong alkaline solutions and
- Lubricate only the upper part of the inner joint. A properly lubricated joint appears clear, without striations.

Equipment Safety

Working in a laboratory requires various types of equipment. To ensure equipment safety, you must always use the correct equipment, know how to operate the equipment and use it properly. Laboratory equipment must be inspected and maintained or repaired by a qualified person. The frequency of the inspection depends on the hazard posed by the equipment, the manufacturer's instructions, or as required by regulations. Records of the maintenance must be kept on file by the laboratory supervisor and be available at all times. All personnel using laboratory equipment must be trained on the proper procedures as outlined in the manufactures documentation and users manuals. The following sections outline general guidelines for a variety of common laboratory equipment.

Laboratory Heating Equipment

The equipment considered here includes: laboratory ovens, Bunsen burners, heating plates and mantles, steam, and oil baths. The hazard associated with working with heating equipment can include:
Personal injury and burns from hot surfaces, liquids, vapors or flames.
Sources of ignition both from hot surfaces, liquids or flames and from electrical components.
Many heating appliances contain electrical elements. If any heating device becomes so worn or damaged that the heating element is exposed, the device should not be used but reported to the supervisor in charge of the laboratory. All heating devices (apart from steam baths) must be kept well away from flammable material.

Ovens

Laboratory ovens are useful for baking or curing material, off-gassing, dehydrating samples and drying glassware. Discontinue use of any oven whose backup thermostat, pilot light or temperature controller has failed. Ovens should not be used to dry any chemical sample that has even moderate volatility and that might pose a hazard because of acute or chronic toxicity unless the oven is constantly vented to a safe exhaust. Glassware rinsed in solvent poses a danger of explosion if dried in an unvented oven. Glassware that has been rinsed with an organic solvent should be rinsed with distilled water before it is placed in a drying oven.

Bunsen Burners

Bunsen burners are used less and less in laboratories. The naked flame is a particularly hazardous ignition source and must never be used near open containers of flammable liquid or in environments where appreciable concentrations of flammable vapor may be present. Pull up long hair tied back so that it does not fall over the face. Never wear plastic or latex gloves, which may ignite in the flame, in the vicinity of Bunsen burners.

IMPORTANT: Never leave an open flame unattended.

Hot Plates, Heating Mantles

Laboratory hot plates are used for heating solutions to 100^{o} C or above when safer steam baths cannot be used. Laboratory personnel should be aware of the electrical spark hazard associated with older hot plates. This hazard arising from either the on-off switch located on the hot plate, the bimetallic thermostat used to regulate the temperature or both. Any newly purchased hot plates should be designed in a way that avoids electrical sparks. Limit use of older hot plates for flammable materials. Do not store volatile flammable materials near a hot plate. Check for corrosion of thermostats. Corroded bimetallic thermostats can be repaired or reconfigured to avoid spark hazards.

Heating mantles are commonly used for heating round-bottomed flasks and other, related reaction vessels. Check the state of the heating element enclosed in a series of layers of fiberglass cloth. If the covering fiberglass cloth is broken or worn do not use. If water or other liquid has been spilled onto the element, report this to the laboratory technician. When using a heating mantle, ensure the mantle and flask are of compatible size.

IMPORTANT: Never plug heating mantles directly into a 110-V line. Always use them with a variable autotransformer to control the input voltage.

Heating Baths, Water Baths

Heating baths keep immersed materials immersed at a constant temperature. They may be filled with a variety of materials, depending on the bath temperature required; they may contain water, mineral oil, glycerin, paraffin or silicone oils, with bath temperatures ranging up to 300^{o}C. Material heated in such a bath should be mounted in such a way that it can be quickly and easily removed from the bath in an emergency. Oil baths are particularly hazardous. Users must be trained on the proper operating procedures and review the user manual.

Steam baths present a danger of scalding from hot steam and care must be taken especially when mounting or removing reaction vessels.

Shakers, Blenders and Sonicators

When used with infectious agents, mixing equipment such as shakers, blenders, sonicators, grinders and homogenizers can release significant amounts of hazardous aerosols, and should be operated inside a biological safety cabinet whenever possible. Equipment such as blenders and stirrers can also produce large amounts of flammable vapours. The hazards associated with this type of equipment can be minimized by:

- Selecting and purchasing equipment with safety features that minimize leaking.
- Selecting and purchasing mixing apparatus with non-sparking motors.
- Checking integrity of gaskets, caps and bottles before using. Discard damaged items.
- Allowing aerosols to settle for at least one minute before opening containers.
- Covering tops of blenders with a disinfectant-soaked towel during operation, when using biohazardous material.

When using a sonicator, immerse the tip deeply enough into the solution to avoid creation of aerosols.

Centrifuges

Centrifugation may present two serious hazards: mechanical failure and dispersion of aerosols. **Centrifuge users must be trained on proper operating procedures and review the user manual.**

Figure 25 Portable Centrifuge

To prevent aerosol release:

- Whenever possible, fill centrifuge tubes, load into rotors, remove from rotors, and open tubes within a biological safety cabinet.
- Use only tubes with tops and stoppers.
- Avoid filling the tubes to the rim.
- Do not use aluminum foil to cap tubes as they may become dislodged in the process.
- Check tubes, bottles, and rotors for cracks and deformities before each use.
- Consider operating small, low-speed centrifuge in a biological safety cabinet if possible.

Electrophoresis Equipment

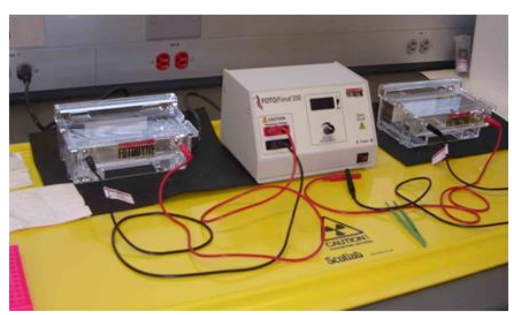
Figure 26 Electrophoresis Units

Supervisors are responsible for providing those under their supervision with appropriate instruction and demonstrating safe use of electrophoresis units. Instruction should cover operating procedures written by the manufacturer and/or laboratory, as well as the associated hazards (e.g. chemicals), the requirement for personal protective equipment (laboratory coats, gloves, and eye protection), and any applicable emergency procedures. Only trained individuals should be allowed to operate electrophoresis apparatus. **Users must be trained on proper operating procedures and review the user manual.**

Electrophoresis units do not need to be operating at high voltages required for procedures such as DNA sequencing to present an electrical shock hazard. Even agarose gel electrophoresis operating at 100 volts or less can cause a lethal shock at a current of 25 milliamps.

Analytical Equipment

The following instructions for safe use of analytical equipment are general guidelines; consult the user's manual for more detailed information on the specific hazards.

- Ensure that installation, modification and repairs of analytical equipment are carried out by authorized service personnel.
- Read and understand the manufacturer's instructions before using this equipment.
- Make sure that preventive maintenance procedures are performed as required.
- Do not attempt to defeat safety interlocks.
- New, modified, or repaired equipment shall be checked for safe operation before being placed into service.
- Equipment, which can be left unattended, should be monitored by occasional inspection to determine any significant malfunctions.
- Wear safety glasses and laboratory coats (and other appropriate personal protective equipment as specified) for all procedures.

Scintillation Counters

- Use sample vials that meet the manufacturer's specifications.
- Keep counters clean and free of foreign material.
- To avoid contaminating the counter and its accessories with radioactivity, change gloves before loading racks in the counter or using the computer keyboard. Verify on a regular basis (by wipe testing) that the equipment has not become contaminated.

Atomic Absorption (AA) Spectrometers

The basic principles of atomic absorption spectroscopy should be well understood before operating the instrument. You must follow basic safety precautions when working with high pressure gases and high temperature flames and furnaces, and a thorough understanding of the instrument is your best protection. Sample preparation for atomic absorption procedures often requires handling of flammable, toxic and corrosive products. Familiarize yourself with the physical, chemical and toxicological properties of these materials and follow the recommended safety precautions. Atomic absorption equipment must be adequately vented, as toxic gases, fumes and vapours are emitted during operation. Other recommendations to follow when carrying out atomic absorption analysis are:

- Wear safety glasses for mechanical protection.
- Check the integrity of the burner, drain and gas systems before use.
- Inspect the drain system regularly; empty the drain bottle frequently when running organic solvents.

- Allow the burner head to cool to room temperature before handling.
- Never leave the flame unattended. A fire extinguisher should be located nearby.
- Avoid viewing the flame or furnace during atomization unless wearing protective eyewear.
- Hollow cathode lamps are under negative pressure and should be handled with care and disposed of properly to minimize implosion risks.

If at any time you have reservations about the use of the instrument, please consult your instructor/supervisor.

Mass Spectrometers (MS)

Mass spectrometry requires the handling of compressed gases and flammable and toxic chemicals. Consult MSDSs for products before using them. Specific precautions for working with the mass spectrometer include:

- Avoid contact with heated parts while the mass spectrometer is in operation.
- Verify gas, pump, and exhaust and drain system tubing and connections before each use.
- Ensure that pumps are vented outside the laboratory, as pump exhaust may contain traces of the samples being analyzed, solvents and reagent gas.
- Used pump oil may also contain traces of analytes and should be handled as hazardous waste.

Gas Chromatographs (GC)

Gas chromatography requires handling compressed gases (nitrogen, hydrogen, argon, and helium), flammable and toxic chemicals. GC may pose the following hazards:

a) Explosive gasses
b) Toxic vapors
c) Asphyxiation
d) Electric shock
e) Open flame

Know the operating instructions set forth in the user's manual for the particular GC you are using and follow all manufacture guidelines.

Figure 27 Gas Chromatograph

- The laboratory shall be kept well ventilated when using the GC as exit ports may discharge dangerous levels of toxic vapors.
- Always be aware that flame ionization detector (FID) gases (hydrogen and air) form explosive mixtures. All gas connections must be properly leak tested at installation.
- High-pressure compressed-gas cylinders must be secured to a firm mounting point, whether they are located internally or externally.
- When it is necessary to perform maintenance on the GC or when changing columns, turn off the hydrogen gas supply at its source.

- The detectors and injectors are kept at a very high temperature and can cause burns when touched. Before working on the detectors or injectors turn the detector or injector ovens off and allow the detectors or injectors to cool first.
- When using hydrogen as fuel (flame ionization FID and nitrogen-phosphorus detectors NPD), ensure that a column or cap is connected to the inlet fitting whenever hydrogen is supplied to the instrument to avoid buildup of explosive hydrogen gas in the oven.
- Use only helium or nitrogen gas, never hydrogen, to condition a chemical trap.
- Radioactive leak test (wipe test) are performed on electron capture detectors (ECDs) by the Chemical Control Centre as required under CNSC regulations.

Nuclear Magnetic Resonance (NMR) Equipment

The main hazards associated with the NMR equipment come from the high electromagnetic fields, the handling of cryogens and high electrical voltages. In general, these hazards may be minimized by limiting access to the NMR rooms to only the NMR staff and users of the instruments who have the required technical understanding and training. Know the operating instructions set forth in the users manual for the particular NMR equipment you are using and follow all manufacture guidelines

The superconducting magnet of NMR instruments produces strong magnetic and electromagnetic fields. Exposure to strong magnetic fields can cause serious injury or death and significant damage to personal property, equipment and data**.** The high magnetic fields can affect the operation of some pacemakers and harm implanted or attached devices, such as prosthetic parts and metal blood vessel clips. Persons with these types of medical concerns should contact their physicians about the possible health risks before entering the facilities which house NMR equipment. **Users must be trained on proper operating procedures and review the user manual.**

Safety recommendations for working with NMR include the following: Clear warning signs are placed and maintained to effectively warn people that they are entering a strong magnetic fields area.

- The stray fields are measured with a gauss meter, and public have restricted access to areas of 5-gauss or higher.
- **Metal objects must remain outside the 5-gauss perimeter.** Strong magnetic field attract objects containing steel, iron, and other ferromagnetic materials, including most ordinary tools, electronic equipment, compressed gas cylinders, steel chairs, and steel carts. Unless restrained, such objects can suddenly fly toward the magnet which can cause personal injury and extensive damage to the probe, Dewar, and superconducting solenoid. Only non-ferromagnetic materials should be used near the instruments.
- Only individuals who have had special training should transfer liquid helium and nitrogen to the instruments**.**
- Ensure that ventilation is sufficient to remove the helium or nitrogen gas exhausted by the instrument. Low Oxygen Alarms are recommended.
- In the event of a "magnet quench," leave the room immediately and contact the NMR facility staff. *A quench refers to the sudden release of gases from the Dewar (possibility of asphyxiation hazard).*
- NMR staff and researchers should spend no longer than reasonably necessary within the marked 5 gauss line for sample changing and adjustments. No other equipment unrelated to the NMR system shall be placed within the 5 gauss line, which should be contained in the NMR rooms themselves.

http://www.bio.cam.ac.uk/nmr/ccmr/safety.html

High Pressure Liquid Chromatography (HPLC) Equipment

HPLC procedures may require handling of compressed gas (helium) and flammable and toxic chemicals. Familiarize yourself with the hazardous properties of these products, as well as recommended precautionary measures, by referring to MSDSs. Know the operating instructions set forth in the user manual for the particular HPLC you are using and follow all manufacture guidelines.

Some recommendations for working with HPLC include:

- Inspect the drain system regularly; empty the waste container frequently when using organic solvents.
- Ensure that waste collection vessels are vented.
- Never use solvents with auto ignition temperatures below 110°C.
- Be sure to use a heavy walled flask if you plan to use vacuum to degas the solvent.
- Never clean a flow cell by forcing solvents through a syringe: syringes under pressure can leak or rupture, resulting in sudden release of syringe contents.
- High voltage and internal moving parts are present in the pump. Switch off the electrical power and disconnect the line cord when performing routine maintenance of the pump.

Liquid Chromatography/Mass Spectrometry (LC/MS) Equipment

LC/MS requires the handling of compressed nitrogen and flammable and toxic chemicals. Consult product MSDSs before using them. Specific precautions for working with LC/MS equipment include:

- Verify gas, pump exhaust and drain system tubing and connections before each use.
- Test the pressure switch for the exhaust line before each use.
- Ensure that pumps are vented outside the laboratory.

X-ray Diffraction/Electron Microscopy

An electron microscope presents several potential safety hazards that must be recognize before it is operated. They are:

- Operates at dangerously high voltages
- production of hazardous x-rays when energized

A badge/dosimeter must be worn by each individual while using X-ray Diffraction and similar equipment which generate high levels of radiation. Know the operating instructions set forth in the user's manual for the particular X-ray equipment you are using and follow all manufacture guidelines.

For more information regarding X-ray Equipment & Safety Please contact the X-Ray safety officer. To apply for badge/dosimeter contact the CCC Radiation Safety Program. The application form is also available at the radiation safety website at www.uwindsor.ca/radiation

Physical Hazards

Physical hazards in laboratories cover a wide range of concerns including the following: cuts, slips, trips, and falls. Broken glassware is a frequent cause of cuts in laboratories. Water on the floor, especially around sinks or ice dispensers may cause slips.

Examples of other physical hazards are: high-voltage electricity, noise, high-pressure systems, microwaves, lasers, and ionizing radiation. Laboratory personnel must identify physical hazards present in the laboratory and implement work practices to avoid injury. Protection from these hazards is generally provided through, safe work practices, training, protective equipment, and engineering controls.

Electrical Hazards[10]

Electricity is a potential ignition source and the cause of more than 25% of fires. Injuries and death from electrical shock can result both from induced malfunction of the heart and lung muscles and from burns. The following are general precautions and recommendations to reduce electrical hazards in the laboratory.

- Know how to cut off the electrical supply to the laboratory in the event of an emergency.
- Maintain free access to panels. Breaker panels should be clearly labeled as to which equipment they control.
- Avoid the use of extension cords and multiple adaptors by ensuring the laboratory is equipped with sufficient outlets.
- Only licensed electricians can perform wiring and direct connections to electrical circuits.
- All electrical outlets should carry a grounding connection requiring a three-pronged plug.
- Never remove the ground pin of a three-pronged plug.
- Remove cords by grasping the plug, not the cord.
- Do not place electrical cords across areas of pedestrian traffic.
- Ensure that all wires are dry before plugging into circuits.
- Use only carbon dioxide, or dry chemical extinguishers on electrical fires.

Electrical Equipment and Apparatus

There are various ways of protecting people from the hazards caused by electricity, including insulation, guarding, grounding, and electrical protective devices.

- All mechanical equipment must be adequately guarded to prevent access to electrical connections or moving parts. (Ontario Regulation 851 Section 25)
- All centrifuges must be fitted with an interlock so that they cannot be accessed while moving or started while open. (Ontario Regulation 851 Section 31)

High Pressure and Vacuum Work

Pressure differences between laboratory apparatus and the atmosphere result in many laboratory accidents. Glass vessels under vacuum or pressure are at risks of implosion and explosion which can cause injuries, including cuts from projectiles and splashes to the skin and eyes. Any piece of glassware

[10] Adapted with permission from Faculty of Engineering, University of Windsor, Laboratory Safety Manual

under vacuum, such as rotary evaporators and water pump traps have the potential to do harm following implosion. Even small pressure differences can rupture glass apparatus. Rapid temperature changes, such as those that occur when removing sample containers from liquid cryogenics, can lead to pressure differences. Know the operating instructions set forth in the user's manual for the particular High Pressure system and/or vacuum you are using and follow all manufacture guidelines.

Mechanical Safety

Foot note(*Adapted with permission from Faculty of Engineering, University of Windsor, Laboratory Safety Manual*)

Figure 29 UWin Mechanical Workshop

In the mechanical workshops there are various hazards caused by moving parts, failure of equipment, incorrect or careless use of hand tools, faulty or damaged tools, etc. Only qualified technicians or staff/students acting under the supervision of suitably qualified technicians as authorized by the Workshops Supervisor may use the workshops facilities.
Beside appropriate PPE and using machine guarding provided, good housekeeping and safe working distances between machines can also minimize the hazards. Operators must be properly trained on operating procedures of machinery.
Always use proper personal protective equipment. . All personnel using laboratory machinery must be trained on the proper procedures as outlined in the manufactures documentation and users manuals.

Machine Safety

Lathes

A lathe is a machine used for shaping a piece of material, such as wood or metal by rotating it rapidly along its axis while pressing against a fixed cutting or abrading tool. Know the operating instructions set forth in the user's manual for the particular lathe you are using and follow all manufacture guidelines.

Milling Machines

A milling machine is a tool used for shaping metal and other solid materials. It consists of a rotating cutter which rotates about the spindle axis (similar to a drill) and a moveable table to which the work piece is affixed. Know the operating instructions set forth in the user's manual for the particular milling machine you are using and follow all manufacture guidelines.

Figure 31 Milling Machine

Band Saws

The band saw is a saw used for cutting wood or metal products. It consists of a narrow, toothed metal blade which rides between two wheels in the same vertical plane. Know the operating instructions set forth in the user's manual for the particular band saw you are using and follow all manufacture guidelines.

Figure 32 Band Saw

Drill Press

A drill press is a fixed style of drill that is mounted on a stand or bolted to the floor. It consists of a base, column, spindle and drill head which is driven by a motor. Know the operating instructions set forth in the user's manual for the particular drill press you are using and follow all manufacture guidelines.

Welding

Welding is a fabrication process that joins materials by melting the work pieces and adding a filler material to form a pool of molten material which cools to become a strong point. Welding is only permitted by authorized individuals.

Figure 33 Welding Process

- Welders, assistants, and anyone else in the welding area must wear appropriate welding helmets during welding operations.
- The welder is responsible for erecting a screen around the welding area to protect other personnel in the area from eye injury.
- All welding equipment to be used must be inspected for possible damage prior to each use.
- Do not handle oxygen bottles with greasy hands, gloves or rags and this is a cause of explosion.
- Welding tanks must be strapped to a welding cart of fixed object. A gas cylinder must never be free stand. Safety cap must be replaced on all cylinders when not in use.
- Be sure work and work table are properly grounded when arc welding.
- Never arc weld in a wet area.
- Be alert to possible fire hazards. Be sure that all flammable materials are removed from the work area. This includes degreasing or other cleaning operations.
- A fire extinguisher should be nearby a work area where welding is being done. Be sure you know how to operate the fire extinguisher.
- Shut off all cylinder valves when the job is complete. Release pressure from the regulators by opening the torch valves momentarily and back out regulator adjusting valves. Never leave the torch unattended with pressure in the hoses.
- Utilize protective equipment and clothing. Every part of the body should be covered.
- Never weld inside enclosed spaces with inadequate ventilation. Check the ventilation system before starting to weld.
- Do not weld on painted, galvanized or greasy, oily metals.

Compressed Air (Pneumatic) Tools

Compressed air can be very dangerous, contrary to what some people may think. Air forced into the tissues or blood stream through the skin can cause an air embolism which can be fatal if it reaches the heart lungs or brain. Ear and eye injuries such as blown eardrums, blindness and deafness can be caused from an air blast or flying particles.

The following safety precautions must be followed when working with compressed air and compressed air (pneumatic) tools. **Users must be trained on proper operating procedures and review the user manual.**

Laser Safety

There are two major safety concerns when it comes to laser safety. The first concern being exposure to the beam and the second being the hazards involved with the high voltages within the laser and its power supply. Although it is possible for beams of sufficient power to burn the skin, the major concern is damage to the eye, since it is the body part which is most sensitive to light. The safety precautions listed below should be followed whenever lasers are being used.

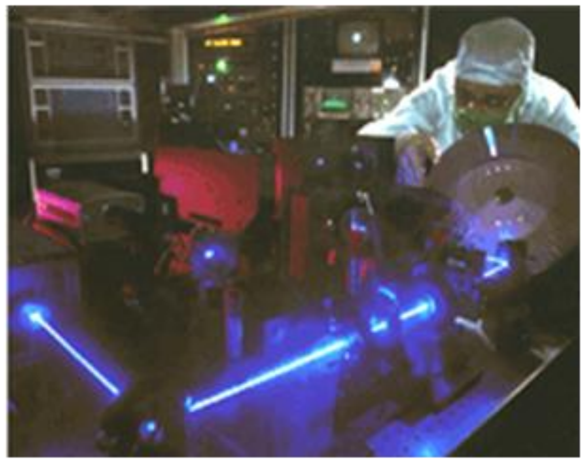

Figure 34 Laser Beam

- All lasers must be registered with the Chemical Control Centre.
- Class 3B and Class 4 lasers are regulated by the province and must have a University of Windsor Laser permit issued by the Laser Safety Officer.
- Only personnel trained in the operation of the laser and laser safety shall be permitted to operate the laser or laser system.
- An individual knowledgeable in laser safety shall directly supervise the laser-controlled area.
- Eye protection shall be provided for all personnel working in laser controlled area.

LASER SAFETY PROGRAM

For detailed information please refer to the University of Windsor's Laser Safety Program for more information on all matters regarding laser permit and training by visiting http://www.uwindsor.ca/laser or contacting the Laser Safety Officer at the Chemical Control Centre, Essex Hall room B-37; ext.3524. The Laser Safety Officer is available at the CCC ext 3524 for consultation, acquisition, set up, usage and disposal of laser products.

Robot Safety

Robots are programmable multifunctional mechanical devices used to move material, parts tools or specialized devices through variable programmed motions to perform a variety of tasks. Studies have shown that many robot accidents do not occur during normal operating conditions but rather during programming, programming refinement, maintenance, set-up and adjustment. It is during these times that workers may be temporarily within the robots working envelope.

The operational characteristics of robots can be significantly different from other machines and equipment. Robots are capable of high energy (fast or powerful) movements through a large volume of space. For this reason it is important to be extremely cautious when working with robots. The following safety precautions should be followed whenever a robot is involved:

- A risk assessment of the robot and robot system should be performed.
- Personnel should be safeguarded from hazards associated within the working envelope
- Special consideration must be given to the teacher or person who is programming the robot. The person performing the teaching has control of the robot and must therefore be familiar with the operations to be programmed, the control functions of the robot and surrounding equipment. The person doing the programming shall be the **only** person within the working envelope of the robot. As well, the speed of the robot should be restricted during teaching operations.

Fire Safety

(Adapted from Occupational Health and Safety Fire Plans and Departmental Laboratory Safety Guidelines, University of Windsor)

Discovery of a Fire

1. Shout "**FIRE, FIRE, FIRE**";
2. **Activate fire alarm by pulling station box located at all exits and/or phone the Campus Police dial extension 911 from a safe location**. Provide location of fire, your name and answer any questions asked by dispatcher.
3. Do not attempt to fight fires that cannot be easily handled.
4. Fight Fire (if safe) following instructions on proper use of fire extinguishers.
5. If you put out a fire with a fire extinguisher, **NEVER WALK AWAY**. Back away and stand by in case the fire reignites.
6. **If fire is too large to use a fire extinguisher, leave the building immediately.**
7. Report all fires, no matter how small. Call Campus Police dialing 911 and make sure everyone is leaving the building.
8. Close windows and doors but **DO NOT LOCK**

1. Evacuate building by the nearest exit;
2. **Never use elevators to evacuate building.**
3. Building Fire Plan Managers **(Orange Vest)** and Fire Wardens will assume a lead role in building evacuation, when in doubt asks.
4. Do not re-enter the building until the all clear has been given by the Building Fire Plan Manager.

Sounding of Evacuation Alarm

1. Upon Hearing the Fire Alarm:
2. Stop all work and remain calm.
3. If safe, turn off any equipment you are using if you have authority to do so.
4. Follow Fire Warden's directions.
5. Leave building via nearest exit. (If you encounter smoke in a stairwell or corridor, use an alternate route.)
6. Close all doors behind you. **DO NOT USE ELEVATORS**.
7. Ensure any handicapped persons are given assistance.
8. Wait for further instruction from the Building Fire Plan Manager at the scene.
9. **DO NOT RE-ENTER THE BUILDING** until the Building Fire Plan Manager declares it safe to do so.
10. The designated meeting area in the event of an extended and/or after-hours evacuation is the CAW Student Centre, which is open 24 hours.

Critical Reminders

1. Only authorized persons including the City of Windsor Fire Department, Campus Police, and Fire Safety personnel shall be permitted to use the elevators during fire emergencies.
2. Firefighting is the responsibility of the City of Windsor Fire Department. If the fire is small or in its earliest stages and can be fought effectively with available fire extinguishers, then you may attempt to extinguish such fires providing there is no life safety hazard to the user and such action will not endanger others.

Yours and your students' safety is the most critical factor, not extinguishing the fire itself!

Medical Emergency

Call University of Windsor Campus Police dial ext. 911. **If there is an emergency in which someone's life is at stake and the loss of a minute or two is critical, then it is appropriate to pull the fire alarm.**

Fire Extinguishers

While proper procedure and training can minimize the chances of an accidental fire, you must still be prepared to deal with a fire emergency should it occur. This document teaches you the basics about fire extinguishers – proper types, how to use them, and when not to use them as well as the proper procedures to follow should a fire occur. It is **not** a comprehensive guide, be sure to read the **DISCLAIMER** given below.

If yours or your student's clothing is on fire (and the floor is not), STOP, DROP, and ROLL on the ground to extinguish the flames. If you are **within a few feet** of a safety shower or fire blanket, you can use these instead, but do not try to make it "just down the hall" if you are on fire. If one of your coworkers or students catches fire and runs down the hallway in panic, tackle them and extinguish their clothing.

Table 7 Types of Fires

Types of Fires	Type of Fire Materials Involved
Class A	Ordinary materials like burning paper, lumber, cardboard, plastics, etc.
Class B	**Flammable** or **combustible** liquids such as gasoline, kerosene, and common **organic solvents** used in the laboratory.
Class C	Energized electrical equipment, such as appliances, switches, panel boxes, power tools, and hot plates and stirrers. **Do not use water to extinguish due to the risk of electrical shock.**
Class D	Combustible metals, such as magnesium, titanium, potassium, and sodium as well as pyrophoric organometallic reagents such as alkyllithiums, Grignards, and diethylzinc. **Do not use water or CO_2 to extinguish due to potentially violent reactions.** The above materials will burn at high temperatures and will react violently with water, air, and/or chemicals. **Handle with care!**

Some fires may be a combination of these. The fire extinguishers have an ABC rating and the higher the number, the more firefighting power it has. The classification of extinguisher in the laboratories is labeled "20 BC".

Table 8 Types of Fire Extinguisher

Type of Extinguisher	Suitability
Water	Useful for class A (paper, etc.) fires only. Use on class B, C, or D fires will cause flames to spread or the hazard made greater.
Dry chemical	**Useful for class ABC fires**. This extinguisher leaves a blanket of non-flammable material on the extinguished material which reduces the likelihood of reigniting. There are two types of dry chemical extinguishers: ***Type BC:*** Contains sodium or potassium bicarbonate ***Type ABC:*** Contains ammonium phosphate
Carbon dioxide (CO_2)	Useful for class B and C fires only. This extinguisher leaves behind no harmful residues. Do not use on class A fires because the material usual reignites. This extinguisher is *not approved for class D* flammable metal fires such as Grignard reagents, alkyllithiums, and sodium metal because CO_2 reacts with these materials.

Typical small fire labs can be easily controlled by the use of sand or with a dry chemical (ABC) extinguisher provided that you are properly trained to use one.

Using Fire Extinguishers

- You are not required to fight a fire... Ever! If you have the slightest doubt about your control of the situation, **DO NOT FIGHT THE FIRE**. **Remember**: your personal safety comes first. Please see the **DISCLAIMER** below.

1. Use a mental checklist to make a Fight-or-Flight Decision. Attempt to use an extinguisher only if **ALL** of the following apply:

   The building is being evacuated (fire alarm is pulled)
   - Campus Police is being called (**to call Campus Police using any campus phone dial 911**)
   - The fire is small, contained and not spreading beyond its starting point.
   - The exit is clear, there is no imminent peril, and you can fight the fire with your back to the exit.
   - You can stay low and avoid smoke.
   - The proper extinguisher is immediately at hand.
   - You have read the instructions and know how to use the extinguisher.

   IF ANY OF THESE CONDITIONS HAVE NOT BEEN MET, DON'T FIGHT THE FIRE YOURSELF. CALL FOR HELP, PULL THE FIRE ALARM AND LEAVE THE AREA.

2. Whenever possible, use the "Buddy System" to have someone back you up when using a fire extinguisher. If you have any doubt about your personal safety, or if you can not extinguish a fire, leave the building but contact a firefighter to relay whatever information you have about the fire.

3. Operating the fire extinguisher:
   Stay low behind the fire extinguisher as the fire usually flashes back over the top of the extinguisher upon the first burst of air. Then:

   P **pull pin**
   A **aim low at base of flame**
   S **squeeze the lever**
   S **sweep from side to side**

   - Do not walk on area that you have "extinguished" in case the fire reignites or the extinguisher runs out! Remember, you usually can't expect more than 10 full seconds of extinguishing power on a typical unit and this can be significantly less if the extinguisher was not properly maintained or partially discharged.
   - Again, proper training is required by provincial or federal laws.

4. Recharge any discharged extinguisher **immediately** after use. If you discharge an extinguisher (even just a tiny bit) or pull the pin for any reason, inform the lab coordinator to arrange a replacement.

DISCLAIMER: These pages contain **guidelines** for the use of fire extinguishers and are not meant to be a comprehensive reference. There are many circumstances that these guidelines can not foresee and you should recognize the inherent danger in relying solely on this information!

Clothing fires

If your clothing should catch fire:
It is important not to run, as this would provide additional air to support the flames.
Remember the "Stop, Drop and Roll" rule:

Stop where you are
Drop to the floor, and
Roll to smother the flames

As soon as the flames are extinguished, go to the nearest emergency shower to cool burned areas with copious amounts of water.

If someone else is on fire:
Immediately immobilize the victim and force him/her to roll on the ground to extinguish the flames. Assist in smothering the flames, using whatever is immediately available, such as a fireproof blanket or clothing. Give appropriate first aid.

Emergency Procedures

Emergency Phone Numbers

Fire Department 911 activate pull station on wall

Ambulance Dispatch 911

Medical Office 7002

Chemical Control Centre 3519, 3523

Poison Control 1-800-268-9017

First Aid Kits - location can be found on web of the Occupational Health & Safety at: www.uwindsor.ca/safety

First aid

(*Taken with permission from McGill University Laboratory Safety Manual)*

It is important to know how to handle emergency situations before they occur. Become familiar with the properties of the hazardous products used in your area. Familiarize yourself with location and contents of the first aid kit and learn how to use them. Keep instructions readily available and easy to understand. Know how to test and operate emergency equipment, such as showers and eye washes in your area. Eye wash and showers are to be tested weekly by appointed staff and annually by facility services. Learn first aid: Contact Occupational Health and Safety for a schedule of approved workplace first aid and CPR (cardiopulmonary resuscitation) course dates.

Burns

In the laboratory, thermal burns may be caused by intense heat, flames, molten metal, steam, etc. Corrosive liquids or solids such as bases and acids can cause chemical burns; first aid treatment for chemical burns is described below. In electrical burns, electrical current passing through the body generates heat.

Poisoning

Toxic substances can enter and poison the body by inhalation, absorption through the skin, ingestion or injection. When assisting a victim of poisoning:

- Call for an ambulance (dial 911) for serious poisoning.
- Ensure that the area is safe to enter before attempting to aid the victim.
- Move the victim away from the contaminated area and provide first aid as required, do not induce vomiting unless advised to do so by a reliable authority such as the Poison Control Centre (1-800-268-9017).
- Provide emergency medical personnel with the MSDS for the poisonous product. If the victim was overcome by an unknown poison and has vomited, provide the ambulance technicians with a sample of the vomits.
- Always ensure that the victim receives medical attention, even if the exposure seems minor.

Hazardous chemical spills

In the event of a spill of a hazardous (volatile, toxic, corrosive, reactive or flammable) chemical, the following procedures should be followed:

1. If there is fire, pull the nearest alarm. If you are unable to control or extinguish a fire, follow the fire evacuation procedures.
2. If the spill is in a laboratory, shop or chemical storeroom:
    - Evacuate all personnel from the room
    - Be sure the hood/local exhaust is turned on
    - If flammable liquids are spilled, disconnect the electricity to sources of ignition if possible
    - Call the campus emergency telephone number 911 to request additional assistance if you cannot manage the clean-up yourself.
3. If the spill is in a corridor or other public passageway:
    - Evacuate all people from the area and close off the area to keep others out.
    - Call the emergency telephone number 911 to have the air system in the area shut down (to prevent contamination of other areas) and to request additional assistance.

Note: For more detailed information on spill clean-up action, refer to guidelines for specific types of spills in the Spill Response Manual, CCC, University of Windsor.

Natural gas leaks

Have the natural gas valves closed if you don't use gas. If you do use gas, and detect a natural gas smell: Check that all gas valves have been turned off. If the odor persists dial 911.

Definitions

Teaching Laboratory

The Teaching Laboratory is designed and equipped to support the teaching programs of the University of Windsor in areas of approved academic courses. In the teaching laboratory a group of students receive instructions and perform experimental procedures.

Research Laboratory

The Research Laboratory is principally set up to carry out research and to educate individuals in advanced laboratory procedures and practice.

Supervisor

A person who has charge of a workplace or authority over a worker. (OH&S Act of Ont. Sec 1(1). At the University this includes all principal investigators, faculty and staff who administer a laboratory or are responsible for guiding the individual(s) doing a research project.

Specific duties are outlined inside this manual.

Laboratory Personnel

At the University this includes all individuals who perform procedures in a laboratory. Some of these individuals may have supervisory functions.

Unattended Procedure

A procedure or equipment which is left operating without anyone present in the laboratory.

Hazardous Material

A hazardous material is any item or agent (biological, chemical, physical, or radioactive) which has the potential to cause harm to humans, animals, or the environment, either by it or through interaction with other factors.

Second Edition

APRIL, 2014

APPENDIX 1

Gloves Selection by Laboratory Hazard

The following table is provided as a guide and covers recommended glove materials for a variety of laboratory hazards.

Table 9 Glove Selection by Laboratory Hazard (from McGill Laboratory Safety Manual, used with permission)

HAZARD	DEGREE OF HAZARD	RECOMMENDED MATERIAL
Abrasion	Severe	Reinforced heavy rubber, staple-reinforced leather
	Less Severe	Rubber, plastic, leather, polyester, nylon, cotton
Sharp Edges	Severe	Metal mesh, staple-reinforced heavy leather, Kevlar, aramid-steel
	Less Severe	Leather, terry cloth (aramid fibre)
	Mild with Delicate Work	Lightweight leather, polyester, nylon, cotton
Chemicals and Liquids	Varies depending on the concentration, contact, time, etc. Consult MSDS manufacturer or permeation chart	Choice depends on chemical. *Examples:* natural nitrile or butyl rubber, neoprene, PTFE(polytetrafluoroethylene), polyvinyl chloride, polyvinyl alcohol, Teflon™, Viton™, Saranex™, 4H™, Chemrel™, Barricade™, Responder™
Cold		Leather, insulated plastic or rubber wool, cotton
Heat	Over 350°C	Asbestos Zetex™
	Up to 350°C	Neoprene-coated asbestos, heat resistant leather with linings, Nomex, Kevlar™
	Up to 200°C	Heat-resistant leather, terry cloth (aramid fibre), Nomex, Kevlar™
	Up to 100°C	Chrome-tanned leather, terry cloth
Electricity		Rubber-insulated gloves tested to appropriate voltage (C.S.A. Standard Z259.4-M1979) with leather outer glove
General Duty		Cotton, terry cloth, leather
Product Contamination		Thin-film plastic; lightweight leather, cotton, polyester nylon
Radiation	Low to moderate toxicity	Any disposable rubber or plastic glove

Appendix 2

Below is a list of some of the materials that may form peroxides in storage, when in contact with air:

- Aldehydes
- Ethers, especially cyclic ethers and those containing primary and secondary alcohol groups
- Compounds containing benzylic hydrogen atoms (particularly if the hydrogens are on tertiary carbon atoms)
- Compounds containing the allylic structure, including most alkenes.
- Vinyl and vinylidene compounds.

Listed below are some of the more widely-used compounds which may form peroxides in storage.

- acetal
- cumene
- cyclohexene
- cyclooctene
- decahydronaphthalene
- decalin
- diacetylene
- dicyclopentadiene
- diethyl ether
- diethylene glycol
- diisopropyl ether - see isopropyl ether
- dimethyl ether
- dioxane
- divinyl acetylene
- ethylene glycol dimethyl ether (glyme)
- isopropyl ether
- methyl acetylene
- sodium amide
- tetrahydrofuran (THF)
- tetrahydronaphthalene
- tetralin
- vinyl acetate
- vinylidene chloride
- vinylidine fluoride [11]

[11] http//msds.chem.ox.ac.uk/DI

Appendix 3

Table 10 Incompatible Combinations for Some Commonly Used Chemical. *Adopted from McGill University Laboratory Safety Manual* (used with permission)

CHEMICAL NAME OR CLASS	MAY PRODUCE REACTIONS WITH
Acetic acid	chromic acid, nitric acid, hydroxyl compounds, perchloric acid, peroxides, permanganate
Ammonia	mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium nitrate	acids, flammable liquids, metal powders, chlorates, nitrates, sulphur, metal powders, finely divided combustible materials.
Aniline	nitric acid, hydrogen peroxide
Carbon, activated	calcium hypochlorite, all oxidizing materials
Flammable liquids	nitric acid, ammonium nitrate, inorganic acids, hydrogen peroxide, sodium peroxide, halogens, chromic acid
Hydrofluoric acid	ammonia, ammonium hydroxide
Hydrogen peroxide	copper, chromium, most metals or their salts, aniline, nitromethane, flammable, liquids, oxidizing gases
Iodine	acetylene, ammonia, hydrogen
Mercury	acetylene, ammonia, fulminic acid
Nitric acid	flammable liquids, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable gases
Perchloric aid	flammable liquids and gases, combustible organic matter, acetic anhydride
Potassium chlorate	sulfuric and other acids
Potassium permanganate	glycerin, ethylene glycol, benzaldehyde, sulfuric acid
Sodium peroxide	alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethylene acetate, methyl acetate, furfural
Sulfuric acid	potassium chlorate, potassium perchlorate, potassium permanganate

Chemical Control Centre
401 Sunset Ave B-37 Essex Hall
Windsor, ON N9B 3P4
ccc@uwindsor.ca
www.uwindsor.ca/ccc