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McGill University
Laboratory Safety Manual

VERSION 2.0

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Contents

1. Introduction to Laboratory Safety

1.1 Preparing for laboratory work

Before starting to work in a laboratory, familiarize yourself with the following:

- The hazards of the materials in the lab, as well as appropriate safe handling, storage and emergency protocols. Read labels and safety data sheets (SDSs) before moving, handling or opening chemicals. Never use a product from an unlabeled container, and report missing labels to your supervisor.
- The agents, processes and equipment in the laboratory. If you are unsure of any aspect of a procedure, check with your supervisor before proceeding.
- The location and operation of safety and emergency equipment such as fire extinguishers, eyewash station and emergency shower, first aid and spill response kits, fire alarm pull stations, telephone and emergency exits
- Emergency spill response procedures for the materials you will handle
- Emergency reporting procedures and telephone numbers
- Designated and alternate escape routes

1.2 During laboratory work

Apply the following rules when working in the laboratory:

- Restrict laboratory access to authorized persons only. Children are not permitted in labs.
- Smoking, eating, drinking, storing food, beverages or tobacco; applying cosmetics or lip balm and handling contact lenses are not permitted in laboratories.
- Wear lab coats (knee length) and safety glasses in laboratories employing chemicals, biohazards or radioisotopes. Open shoes, such as sandals, should never be worn in the lab.
- Tie back or otherwise restrain long hair when working with chemicals, biohazardous products, radioisotopes, or moving machinery.
- Keep work places clean and free of unwanted chemicals, biological specimens, radioactive materials and idle equipment. Avoid leaving reagent bottles, empty or full, on the floor.
- Work only with materials once you know their flammability, reactivity, toxicity, safe handling and storage and emergency procedures.
- Consult safety data sheets (SDS) before working with hazardous chemicals or infectious material. Ensure you have access to the SDSs for the products you handle.
- Prepare and maintain a chemical inventory for the lab.
- Never pipette by mouth; use mechanical transfer devices.
- Walk, do not run, in the lab.
- Keep exits and passageways clear at all times.
- Ensure that access to emergency equipment (eyewash stations, emergency showers and fire extinguishers) is not blocked.
- Report accidents and dangerous incidents ("near-misses") promptly to your supervisor
- Wash your hands thoroughly before leaving the laboratory.
- Conduct procedures involving the release of volatile toxic or flammable materials in a chemical fume hood (See Section 7.4).

- Perform procedures that liberate infectious bioaerosols in a biological safety cabinet
- Handle all human blood and body fluids as if potentially infectious
- Keep music at a moderate level and refrain from using ear buds or headphones

1.3 Cleaning up before leaving

Perform a safety check at the end of each experiment and before leaving the lab. Make sure to:

- Turn off gas, water, electricity, vacuum and compression lines and heating apparatus
- Return unused materials, equipment and apparatus to their proper storage locations
- Label, package and dispose of all waste material properly (Refer to Section 6.3)
- 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 (lab coats, gloves, etc.) when leaving the laboratory
- Close and lock the door to the laboratory if you are the last one to leave

1.4 Evaluating laboratory hazards, an ongoing process

There are many categories of hazards that might be encountered in a laboratory setting, and situations can change frequently. Even after you have identified and controlled all current risks, it is critical that you remain open to the possibility that new unexpected dangers can arise. Periodically verify that the Laboratory Information Card (LIC) and other hazard warnings are current; update and replace whenever changes to the LIC are required.

Carry out weekly inspections on the condition of:

- fire extinguishers
- emergency wash devices such as eyewash stations and drench hoses (run these for several minutes and update inspection tags
- first aid kit contents
- fume hood and other ventilation devices
- tubing for circulating water, vacuum, gases
- chemical storage compartments

Also, ensure that fire extinguishers and emergency showers are inspected, tested and tagged annually.

Among potential laboratory hazards, be alert for the following:

- **Chemical products**
  - flammable
  - toxic
  - oxidizing
  - reactive
  - corrosive

- **Microbiological disease-producing agents and their toxins**
    - viruses
    - bacteria
    - parasites
    - rickettsiae
    - fungi

- **Physical or mechanical hazards**
    - ionizing and non-ionizing radiation
    - electrical
    - poor equipment design or work organization (ergonomic hazards) tripping hazards
    - excessive noise or heat

- **Psychosocial conditions that can cause psychological stress**

1.5 Working alone policy

Working alone is an unsafe practice at any time. However, if the nature of your work makes it unavoidable, take measures to ensure that others are aware of your location and have someone check in with you from time to time, either in person or by telephone.

Before conducting any work alone in a laboratory go through this checklist to determine if it is appropriate to proceed:

- Is your supervisor aware of your plans?
- Are there any hazardous experiments involved?

  Examples:

  - High temperature
  - High vacuum
  - Extremely flammable materials (low flash point)
  - Poisonous materials
  - Scaling up i.e., higher quantities

- Have you reviewed your procedure with your supervisor?
- Do you have a written operating procedure?
- Are your apparatus and equipment in good working condition?
- Are you trained to carry out the work?
- Do you have a check-in/check-out procedure?
- Do you have an emergency contingency?
- Do you have access to a McGill telephone (rather than a cell) in case of an emergency?
- Does your door have a viewing window or other means of indicating someone is inside?
- Are you aware of the emergency evacuations procedure?
- Do you have access to a telephone in case of an emergency?

- Do you have access to a first aid kit?
- Do you have access to a spill kit?

Please complete and post the Notice of Working Alone in the Laboratory form outside of your laboratory.

2. Workplace Hazardous Materials Information System (WHMIS)

Workplace Hazardous Materials Information System (WHMIS) is a Canada-wide system for providing information on the safe use of hazardous materials, referred to as hazardous products, in the workplace. It is intended to protect the health and safety of workers by promoting access to information on hazardous materials; this information is provided by means of product labels, Safety Data Sheets (SDS) and education programs. Originally enacted in 1989, WHMIS was modified in 2015 to harmonize it with the international community.

WHMIS is governed by federal and provincial laws and regulations (An Act Respecting Occupational Health and Safety (AROHS) (R.S.Q., c. S-2.1) and Hazardous Products Information Regulation (S-2.1, r.8.1) and any person supplying or using hazardous products must comply with its requirements. At McGill, WHMIS legislation applies to all faculty, staff, post docs, students (graduate and undergraduate) and visitors who work in areas where hazardous materials are used.

Hazardous products are products, materials, and substances that are regulated by WHMIS legislation, based on their hazardous properties and characteristics. WHMIS divides hazardous materials into two main hazard groups and 31 hazard classes based on their nature of hazards and specific properties. See Section 2.1.

The main objective of WHMIS is to protect the workers from the adverse effects of hazardous products. WHMIS consists of four main components:

- Classification
- Labels
- Safety Data Sheets (SDS)
- Training

2.1 Regulatory Requirements: Classification, Labels, Safety Data Sheets & Training

2.1.1 Classification

The WHMIS hazardous products are divided in two main hazard groups: Physical Hazard Group and Health Hazard Group. Each hazard group is sub-divided into multiple hazard classes based on their nature of hazards and specific properties.

The Physical Hazard Groups contains 19 hazard classes:

- Flammable Gases
- Flammable Aerosols
- Oxidizing Gases
- Gases under Pressure
- Flammable Liquids

- Flammable Solids
- Self-Reactive Substances
- Pyrophoric Liquids
- Pyrophoric Solids
- Pyrophoric Gases
- Self-Heating Substances
- Substances which, in contact with water emit flammable gases
- Oxidizing Liquids
- Oxidizing Solids
- Organic Peroxides
- Combustible Dusts
- Simple Asphyxiants
- Corrosive to Metals
- Physical Hazards Not Otherwise Classified

The Health Hazard Group contains 12 hazard classes:

- Acute Toxicity
- Skin Corrosion/Irritation
- Serious Eye Damage/ Eye Irritation
- Respiratory or Skin Sensitization
- Germ Cell Mutagenicity
- Carcinogenicity
- Reproductive Toxicology
- Specific Target Organ Toxicity - Single Exposure
- Specific Target Organ Toxicity - Repeated Exposure
- Aspiration Toxicity
- Health Hazards Not Otherwise Classified
- Biohazardous Infectious Materials

2.1.2 Labelling

Labels alert people to the dangers of the product and provide basic safety precautions. It is imperative that all containers in laboratories are clearly identified.
WHMIS legislation dictates what information is required on a workplace label. Any hazardous material, whether in transit, storage, or use, must be labelled. A label may be a mark, sign, stamp, device, sticker, ticket, tag, or wrapper and must be attached to, imprinted, stenciled, or embossed on the container of the hazardous product.

There are 2 types of labels prescribed under WHMIS regulation: supplier labels and workplace labels.

2.1.2.1 Supplier's Labels

Suppliers are responsible for labelling WHMIS hazardous products. A supplier label must contain the following information:

- product identifier (name of product)
- supplier identifier (name of company that sold it and contact information)
- pictograms (WHMIS hazard symbols)

- signal word (severity of the hazard)
- hazard statements (nature of the hazard)
- precautionary statements (how to work with the product safely)
- supplemental information (optional – i.e. ingredients, percentage, etc)

Supplier labels must be provided in both official languages (English and French).

2.1.2.2 Workplace Labels

A workplace label must appear on all WHMIS hazardous products when:

- the hazardous products are produced, prepared or used (e.g., stock solutions) at the workplace;
- the hazardous product is transferred from the original container into another container; and
- the original supplier label becomes illegible or damaged or when it is removed;

A workplace label must contain the following information:

- product identifier (product name)
- information for the safe handling of the product
- reference to the SDS

The product name must include the full name of the product or solution, as it appears on the safety data sheet and include its concentration.

2.1.2.3 Workplace Labels in Research Laboratories

WHMIS legislation does not provide exemptions in the labelling requirements for WHMIS hazardous products in laboratories involved with research and development. When a hazardous product is manufactured, transferred, used, analyzed or stored in research laboratories at McGill, and the container requires a workplace label, the following conditions are mandatory:

- the product is not transported outside the laboratory; and
- the Safety Data Sheet is available.

In McGill research laboratories, the workplace label affixed to the container must contain the following information:

- product identifier (product name)

The product name can either be:

- the full name of the product or solution, as it appears on the safety data sheet and including its concentration

OR

- the approved product abbreviation, as it appears on the **EHS Approved Lab Abbreviations List**

If several small containers are stored in the same area (i.e. same shelf, same tray, etc), only one research lab workplace label is accepted to be affixed to the storage area (shelf, tray, etc). However, once a small container is removed from this area, the container must be labelled.

Abbreviations are not permitted, unless they appear on the **EHS Approved Lab Abbreviations List**. See Section 2.1.2.4.

When a non-WHMIS hazardous product is manufactured, prepared or transferred from one container to another, the label affixed to the container must indicate:

- the product name (abbreviations and chemical formulas permitted)

2.1.2.4 EHS Approved Lab Abbreviations List

EHS has compiled an approved list of laboratory abbreviations. This list permits laboratories to use abbreviations on the labels of those products listed.

- EHS Approved Lab Abbreviations List

In order to use these abbreviations, the EHS Approved Lab Abbreviations List must be posted in the laboratory, preferably in a location close to where the products are stored.

- These conditions will be verified during Laboratory Safety Inspections.

The list will be reviewed annually by EHS. If you wish to make suggestions or recommendations for new abbreviations, email EHS (Subject: Lab Abbreviations) and include the full name of the product, the CAS number and attach an electronic copy of the product's SDS.

2.1.2.5 Laboratory Sample Labels

Laboratory samples are samples intended solely to be tested in a laboratory or used for educational or demonstration purposes. Laboratory samples do not include WHMIS hazardous products that are used by the laboratory for testing other products, materials or substances (e.g., buffer solutions).

The requirements for laboratory samples that are intended 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 lab book); and
- Safety Data Sheets 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)

- lab 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 (see Section 2.1.2). Laboratory samples CANNOT be sent via internal mail.

2.1.3 Safety Data Sheets (SDS)

Safety Data Sheets (SDS) provide more details than labels. They are technical bulletins that provide chemical, physical, and toxicological information about each hazardous product, as well as information on precautionary and emergency procedures. They must be readily accessible to anyone who works with, or who may otherwise be exposed to hazardous products.

2.1.3.1 Supplier's Responsibilities

Suppliers of WHMIS hazardous products are required to prepare and make available the SDS to the purchaser. The SDS must be available in both official languages (French and English). Should any new information arise about a product, the Supplier is required to revise the SDS.

2.1.3.2 Laboratory's Responsibilities

Everyone has the right to review an SDS, whether it is related to their work, or simply because of personal interest.

Every lab at McGill must comply with the Hazardous Products Information Regulation (S-2.1, r. 8.1) which states (chapter 20):

"The employer must keep a safety data sheet for each hazardous product present in the workplace, in a place that is known to the workers and so long as the hazardous product remains present in that workplace.

The employer may keep the safety data sheet on the medium of the employer's choice, including a technology-based medium, to the extent that the safety data sheet is easily legible and rapidly available in hard copy to a worker likely to be exposed to a hazardous product." (S.Q. 2015, c. 13, s. 14)

The following applies to all laboratories involved with research and development, regardless of the number of hazardous products on-hand.

Each laboratory is responsible for ensuring that:

- the SDSs for all WHMIS-hazardous products in the laboratory are available;
- the SDSs for all consumer products (e.g., Bleach, Windex) in the laboratory are available;
- the SDSs are updated when new information becomes available; and
- the SDSs are readily accessible to anyone who works with, or who may be exposed to the products.

In order to simplify SDS management, Principal Investigators and Laboratory Supervisors with multiple

laboratories can have a central SDS collection. All lab personnel, including students, must have access 24/7 to the SDS Collection;

2.1.3.3 SDS location

WHMIS legislation requires that a SDS be readily accessible to anyone who works with, or who may be exposed to hazardous products.

All laboratory personnel must be advised as to the location of the SDS collection and must be able to gain access to the safety data sheets at any time.

At McGill, the SDS collection is available in electronic format via myLab system. All staff and students working with hazardous products must have access to the myLab account of their supervisor in order to get access to the SDS collection.

More information on myLab system can be found here.

2.1.3.4 SDS location indicated on Laboratory Information Card

The Laboratory Information Card must refer to myLab system as the mandatory location of the SDS collection in the laboratory. If the lab supervisor decides to keep paper copies of the SDS in binders, the second location must be mentioned on the Laboratory Information Card (e.g. second shelf on the bookshelf).

2.1.3.5 SDS Audit

During Laboratory Safety Inspections, the EHS inspector will check if the staff and students in laboratory have access to the SDS collection through myLab system.

2.1.4 Training

Training and education provide more detailed instruction on the specific procedures necessary to carry out work safely. WHMIS training is a major component of the WHMIS legislation and therefore is mandatory for all personnel working with hazardous products at McGill, including Principal Investigators, students and visiting researcher.

Training can be divided into two parts: Core Training and Job-specific Training.

2.1.4.1 Core WHMIS Training

Core WHMIS Training is basic training that provides information on classification of hazardous products; it includes the main risks and safety precautions, and the content, purpose and interpretation of information found on labels and in SDS.

Core WHMIS Training for Laboratory Personnel is provided by Environmental Health & Safety and is mandatory for all faculty, staff and students, including undergraduate students working on research projects. The training is valid for a period of 3 years. Core WHMIS Training is offered several times per semester and the schedule can be consulted at www.mcgill.ca/ehs/training/whmis/.

2.1.4.2 Job-specific WHMIS Training

Job-specific training refers to instruction in the procedures for the safe handling and storage of the WHMIS hazardous products that are unique to each laboratory, and includes spill or leak

remediation; waste disposal; and basic first aid instructions. Job-specific training is the responsibility of Principal Investigators and Laboratory Supervisors.

Environmental Health & Safety tracks all safety training on campus and is able to supply supervisors with up-to-date safety training lists for all their personnel, including students. To request a safety training attendance list, send an e-mail to EHS.

2.2 Understanding hazard warning information

2.2.1 WHMIS Pictograms

WHMIS Regulation contains 9 pictograms divided in the two hazard groups. The pictogram for corrosives appears in both hazard groups because these products present physical and health hazard.

The WHMIS pictograms are linked to one or multiple hazard classes. Please find below in Table 1 the list of the hazard classes associated with each WHMIS pictogram.

Table 1 – *List of WHMIS hazards classes associated with the WHMIS pictograms*

WHMIS PICTOGRAMS	HAZARD CLASSES
Flame Pictogram 	• Flammable gases • Flammable aerosols • Flammable liquids • Flammable solids • Pyrophoric liquids • Pyrophoric solids • Pyrophoric gases • Self-heating substances and mixtures • Substances and mixtures which, in contact with water, emit flammable gases • Self-reactive substances and mixtures (excepting Types A and B) • Organic peroxides (excepting Types A and B)
Oxidizing Pictogram 	• Oxidizing gases • Oxidizing liquids • Oxidizing solids
Exploding Bomb Pictogram	• Self-reactive substances and mixtures (only Types A and B) • Organic peroxides (only Types A and B)

	
Corrosion Pictogram 	• Corrosive to metals • Skin corrosion/irritation - Skin corrosion • Serious eye damage/eye irritation - Serious eye damage
Gas Cylinder Pictogram 	• Gases under pressure (Compressed gas, Liquefied gas, Refrigerated liquefied gas, and Dissolved gas)
Skull and Crossbones Pictogram 	• Acute toxicity (Oral, Dermal, Inhalation)
Health Hazard Pictogram 	• Respiratory or skin sensitization - Respiratory sensitizer • Germ cell mutagenicity • Carcinogenicity • Reproductive toxicity • Specific Target Organ Toxicity - Single exposure • Specific Target Organ Toxicity - Repeated exposure • Aspiration hazard
Exclamation Mark Pictogram 	• Acute toxicity – Oral, Dermal, Inhalation • Skin corrosion/irritation – Skin irritation • Serious eye damage/eye irritation – Eye irritation • Respiratory or skin sensitization – Skin sensitizer • Specific target organ toxicity – Single exposure

Biohazardous Infectious Materials Pictogram 	• Biohazardous Infectious Materials

The WHMIS pictograms and their corresponding characteristics / properties and safety precautions are outlined in Table 2:

Table 2 – *Safe handling of hazardous products. Summary of general characteristics and safety precautions for handling and storage of WHMIS hazardous products*

PHYSICAL HAZARDS		
WHMIS PICTOGRAMS	**MAIN CHARACTERISTICS / PROPERTIES**	**MAIN SAFETY PRECAUTIONS**
Flame Pictogram 	• May burn or explode when exposed to heat, sparks or flames • Burns readily at room temperature • Risk of asphyxiation • Health hazards (toxic, irritant, etc.) • Pyrophoric substances - Ignite instantly when exposed to air	• Do not store near oxidizing products • Store away from sources of heat, sparks and flame • Do not smoke near these materials • Never leave experiments unattended • Use only in fume hood
Oxidizing Pictogram 	• Can cause other materials to burn or explode by providing oxygen • May burn skin and eyes on contact • May be toxic or corrosive	• Do not store near flammable products • Store away from sources of heat and ignition • Avoid buying large containers • Use in fume hood if required
Exploding Bomb Pictogram 	• Heating may occur when handled or stored incorrectly • Can cause fire / explosion • Very reactive, can ignite easily and burn quickly • Sensitive to temperature changes, light, friction	• Use only in fume hood • Use small amounts • Keep away from incompatibilities • Discard expired products • Store away from heat • Avoid shock and friction

Corrosion Pictogram 	• Will burn eyes and skin on contact • Will burn tissues of respiratory tract if inhaled • Health effect likely irreversible • Corrosive to metals	• Store acids and bases in separate areas • Avoid inhaling these products • Avoid contact with skin and eyes • Use in fume hood if required • Use containment during transport
Gas Cylinder Pictogram 	• Products under pressure or chilled • The cylinder may explode if heated or damaged • Sudden release of high pressure gas streams may puncture skin and cause fatal embolism • Risk of asphyxiation	• Transport and handle with care • Make sure cylinders are properly secured • Store away from sources of heat or fire • Use proper regulator • Install protective cap when not in use • For cryogenic fluids: use insulated gloves and face shield in addition to PPE

HEALTH HAZARDS		
WHMIS PICTOGRAMS	**MAIN CHARACTERISTICS / PROPERTIES**	**MAIN SAFETY PRECAUTIONS**
Skull and Crossbones Pictogram 	• May cause immediate death or serious injury if inhaled, swallowed or absorbed through the skin • Acute health effect (in a short period of time after exposure)	• Replace with less hazardous products • Avoid inhaling gas or vapours • Avoid skin and eye contact • Avoid stockpiling – minimize amounts • Use fume hood if required • Good housekeeping (clean work surface) • Wash hands after handling & before leaving
Health Hazard Pictogram 	• Chronic health effect (exposure over longer period of time - from days to years) • Cancer-causing products • Lead to respiratory sensitization	
Exclamation Mark Pictogram	• Delayed health effect • Usually reversible and short duration • Dermal sensitizers (itching, redness, etc.)	

	• Reversible skin damage (inflammation) • Irritation of respiratory tract (coughing) • Eye irritation	
Biohazardous Infectious Materials Pictogram 	• Microbiological agents b(e.g. bacteria, viruses, fungi and their toxins) that may cause illness or death	• Work with these materials in designated areas • Disinfect area after handling • Wash hands after handling

COMMON SAFETY PRECAUTIONS:

- Use proper protective equipment (PPE): closed lab coat, closed shoes, safety gloves, and safety glasses
- No food or drink in work areas

2.2.2 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 litre or cubic metre of air (mg/L or mg/m3) 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.

2.2.3 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.

2.2.4 Flash point

The flash point is the lowest temperature at which a liquid produces enough vapour to ignite in the presence of a source of ignition. The lower the flash point, the greater the risk of fire. Many common laboratory solvents (e.g., acetone, benzene, diethyl ether, methanol) have flash points that are below room temperature.

2.2.5 Autoignition temperature

The ignition or autoignition 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 vapour reaches its autoignition temperature. The lower the ignition temperature, the greater the potential for a fire started by typical laboratory equipment.

2.2.6 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 vapour 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 vapour 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 3 -*Flash points, lower explosive limits and exposure limits (8-hour time-weighted averages) of several flammable or combustible laboratory solvents.*

Solvent	FPL (oC)	LEL (% by volume)	Auto ignition temp (C)	TLV-TWA * ppm (mg/m3)
acetic acid, glacial	39	4.0	427	10 (25)
acetone	-18	2.5	538	250 (590)
acetonitrile	5.6	3.0	524	20 (34)
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 (350)
Toluene	4.4	1.1	552	100 (375)

* NIOSH Pocket Guide to Chemical Hazards, 1999

3. Control of Chemical Hazards

3.1 Toxic chemicals and the four routes of entry

Chemicals can gain entry into the body by:

- **Inhalation** of gases, vapours and particulate material (e.g. mists, dusts, smoke, fumes)
- **Absorption** through skin of liquids, solids, gases and vapours
- **Ingestion** of chemicals directly or indirectly via contaminated foods and beverages and contact between mouth and contaminated hands (nail-biting, smoking)
- **Injection** of chemicals through needles and other contaminated laboratory sharps

3.2 Flammable chemicals

Flammable and combustible liquids, solids or gases will ignite when exposed to heat, sparks or flame. Flammable materials burn readily at room temperature, while combustible materials must be heated before they will burn. Flammable liquids or their vapours are the most common fire hazards in laboratories. Refer to Section 5.4 for specific details on the safe handling of flammable chemicals in the laboratory.

3.3 Oxidizing chemicals

Oxidizers provide oxidizing elements such as oxygen or chlorine, and are capable of igniting flammable and combustible material even in an oxygen-deficient atmosphere (Refer to Section 5.1). Oxidizing chemicals can increase the speed and intensity of a fire by adding to the oxygen supply, causing materials that would normally not burn to ignite and burn rapidly. Oxidizers can also:

- React with other chemicals, resulting in release of toxic gases
- Decompose and liberate toxic gases when heated
- Burn or irritate skin, eyes, breathing passages and other tissues

Precautions to follow when using and storing oxidizers in the laboratory include the following:

- Keep away from flammable and combustible materials
- Keep containers tightly closed unless otherwise indicated by the supplier
- Mix and dilute according to the supplier's instructions
- To prevent release of corrosive dusts, purchase in liquid instead of dry form
- Reduce reactivity of solutions by diluting with water
- Wear appropriate skin and eye protection

- Ensure that oxidizers are compatible with other oxidizers in the same storage area

3.4 Reactive chemicals

- May be sensitive to jarring, compression, heat or light
- May react dangerously with water or air
- May burn, explode or yield flammable or toxic gases when mixed with incompatible materials
- Can vigorously decompose, polymerize or condense
- Can also be toxic, corrosive, oxidizing or flammable
- Some chemicals may not be dangerous when purchased but may develop hazardous properties over time (e.g. diethyl ether and solutions of picric acid).

Follow these precautions when working with dangerously reactive chemicals:

- Understand the hazards associated with these chemicals and use them under conditions which keep them stable
- Store and handle away from incompatible chemicals
- Keep water-reactive chemicals away from potential contact with water, such as plumbing, fire sprinkler heads and water baths
- Handle in a chemical fume hood
- Wear the appropriate skin and eye protection
- Work with small quantities
- Use up or dispose of these chemicals before they attain their expiry date

3.5 Corrosive chemicals

Corrosives are materials, such as acids and bases (caustics, alkalis) which can damage body tissues as a result of splashing, inhalation or ingestion. Also:

- They may damage metals, releasing flammable hydrogen gas
- They may damage some plastics
- Some corrosives, such as sulphuric, nitric and perchloric acids, are also oxidizers; thus they are incompatible with flammable or combustible material
- They may release toxic or explosive products when reacted with other chemicals
- They may liberate heat when mixed with water

Precautions for handling corrosive materials include:

- Wear appropriate skin and eye protection
- Use in the weakest concentration possible
- Handle in a chemical fume hood
- Use secondary containers when transporting and storing corrosives
- Always dilute by adding acids to water
- Dilute and mix slowly

- Store acids separately from gases

3.5.1 Guidelines for Safe Use of Corrosive Chemicals

Certain corrosive chemicals require special attention when handled. EHS prepared guidelines to provide safety precautions and information on following products

- Picric acid
- Hydrofluoric acid

3.6 Chemical spill response

3.6.1 Spill response contingencies

Laboratory heads are responsible for predetermining procedures for response to the types of spill situations that may be anticipated for their operations. Individuals requiring assistance in preparing spill response plans should contact ***Environmental Health and Safety (local 4563)***.

In instances where more extensive equipment or technical assistance is needed, backup can be provided by other internal resources. Communications are handled through the emergency telephone number (Downtown Campus **local 3000**, or Macdonald Campus **local 7777**).

The Hazardous Waste Management Department provides the McGill community with a Hazardous Materials (HAZMAT) Spill Response service for all types of accidental spills.

3.6.2 Development of spill response plans

3.6.2.1 Communications

All laboratories housing hazardous materials are required to provide means of reaching contact people who may be summoned in the event of emergencies involving their laboratory, especially for after-hours situations. This may involve posting the relevant telephone number(s) and/or providing them to the Security Services, who operate the emergency telephone number.

Building Directors are also required to provide to the Security Services telephone numbers where they, or alternate contact persons, may be reached during after-hours crises.

3.6.2.2 General guidelines

The following factors are to be considered when developing spill response procedures:

- Categories of chemicals (e.g. oxidizers, flammable solvents) and their chemical, physical and toxicological properties.
- The quantities that may be released.
- Possible locations of release (e.g. laboratory, corridor).
- Personal protective equipment needed.
- Types and quantities of neutralizing or absorbing material needed.

These guidelines should be followed when initially responding to a spill situation:

- Determine appropriate clean up method by referring to the Material Safety Data Sheet (MSDS). 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.
- 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 emergency telephone number (Downtown Campus local 3000, Macdonald Campus local 7777) to request assistance.

3.6.3 Guidelines for specific types of spills

This section describes how to clean up some of the chemical spills that may occur in the laboratory. Refer to Section 6.3.1 for details on how to dispose of the absorbed chemical.

3.6.3.1 Flammable and toxic liquids

- If you can do so without putting yourself at risk, immediately shut off all potential ignition sources
- If fire occurs, alert everyone present and extinguish all flames. If the fire cannot be controlled immediately pull the nearest fire alarm.
- If no flames are evident, pour adsorbent around the perimeter of the spill and then cover the rest of the material. Wear an appropriate respirator if toxic vapours are involved.
- Wear gloves resistant to the chemical being handled. Using a plastic utensil (to avoid creating sparks), scoop up the absorbed spill, place it in a plastic bag, seal it, and place in a labeled container.

3.6.3.2 Corrosive liquids

- Alert everyone present. If vapours are being released, clear the area.
- Do not attempt to wipe up a corrosive liquid unless it is very dilute.
- Gloves, boots, apron and eye protection must be used when neutralizing an extensive corrosive spill. Respiratory protection is required if the liquid releases corrosive vapour or gas.
- Pour the required neutralizing or adsorbing material around the perimeter of the spill, then carefully add water and more neutralizing material to the contained area. Carefully agitate to promote neutralization.
- Use pH paper to verify that all contaminated areas are neutralized and safe to wipe up.
- If an adsorbent (eg. spill control pillows) is used instead of a neutralizer, scoop up the absorbed spill, place it in a plastic bag, seal it, and then place in a labeled box. If neutralized material contains no toxic heavy metals (e.g. chromium), flush down the drain with plenty of water.

3.6.3.3 Corrosive solids

Small spills can be cleaned up mechanically with a dustpan and brush. Larger spills should be cleaned up using a HEPA (high-efficiency articulate) filter vacuum. For spills containing fine dusts, an air-purifying respirator with dust filters is recommended, as are gloves, protective goggles, and a lab coat.

3.6.3.4 Toxic solids

Avoid disturbing such solids (e.g. asbestos) which may release toxic dusts. Wet the material thoroughly, then place it in a plastic bag and label it appropriately. If wet removal is not possible, a vacuum equipped with a HEPA (High Efficiency Particulate Air) filter is required.

3.6.3.5 Gases

In the event of the release of a corrosive gas (e.g. chlorine) or gases that are absorbed through the skin (e.g. hydrogen cyanide), a complete chemical resistant suit and a self-contained breathing apparatus are required. There is no practical means of absorbing or neutralizing a gas - the leak must be corrected at the source.

3.6.3.6 Mercury

If a small amount of mercury is spilled (e.g. broken thermometer), use an aspirator bulb or a mercury sponge to pick up droplets, place the mercury in a container, cover with water, seal it, and label the bottle appropriately. To clean up the residual micro-droplets that may have worked into cracks and other hard-to-clean areas, sprinkle sulphur powder or other commercially available product for mercury decontamination. Leave the material for several hours and sweep up solid into a plastic bag, seal it and label it appropriately.

Contact the ***Environmental Health and Safety (local 4563)*** for monitoring of mercury air concentrations.

If a large spill of mercury is involved, the area should be closed off, and a mercury respirator worn during the clean-up. A mercury vacuum is available from the Hazardous ***Waste Management Department (local 5066)*** for large mercury spills.

3.6.3.7 Special categories

It is not within the scope of this manual to list procedures for all possible categories of chemicals. For further information on responses to other categories consult the safety data sheet or contact ***Environmental Health and Safety (local 4563)***.

4. Storage and Handling in Laboratories

4.1 General Storage Guidelines

- Do not block access to emergency safety equipment such as fire extinguishers, eyewashes, showers, first aid kits or utility controls such as breaker boxes or gas shut-off valves
- Avoid blocking exits or normal paths of travel: keep hallways, walkways and stairs clear of chemicals, boxes, equipment and shelf projections
- Ensure that the weight of stored material does not exceed the load-bearing capacity of shelves or cabinets
- Ensure that wall-mounted shelving has heavy-duty brackets and supports and is attached to studs or solid blocking. Regularly inspect clamps, supports, shelf brackets and other shelving hardware
- Arrange items so that they do not overhang or project beyond the edges of shelves or counter tops
- Do not stack materials so high that stability is compromised
- Leave a minimum of 18 inches (45.7 cm) of clearance between sprinkler heads and the top of

storage

- Use a safety step or stepladder to access higher items; never stand on a stool or a chair

4.2 Ergonomics

- Store frequently used items between knee and shoulder height
- Store heavy objects on lower shelves

4.3 Chemical Storage

- Store hazardous chemicals in an area that is accessible only to authorized laboratory workers
- Minimize quantities and container sizes kept in the lab
- Do not store chemicals in aisles, under sinks or on floors, desks or bench tops
- Store chemicals away from sources of heat (e.g., ovens or steam pipes) and direct sunlight
- Never stack bottles on top of each other
- Do not store chemicals above eye level/shoulder height
- Store larger containers on lower shelves
- Store liquids inside chemically-resistant secondary containers (such as trays or tubs) that are large enough to hold spills
- Store chemicals inside closable cabinets or on sturdy shelving that has 12.7 mm-19 mm (½ - ¾ inch) edge guards to prevent containers from falling
- Ensure that chemicals cannot fall off the rear of shelves
- Store chemicals based on compatibility and not in alphabetical order (refer to Table 3 and Table 4 below). If a chemical presents more than one hazard, segregate according to the primary hazard
- Designate specific storage areas for each class of chemical, and return reagents to those locations after each use
- Store volatile toxic and odorous chemicals in a way that prevents release of vapours (e.g., inside closed secondary containers, ventilated cabinets, paraffin sealing)
- Store flammables requiring refrigeration in explosion-safe or lab-safe refrigerators
- Label reactive or unstable chemicals (e.g., ethers) with the date of receipt and the date opened
- Inspect chemicals weekly for signs of deterioration and for label integrity
- Dispose of unwanted chemicals promptly through the Hazardous Waste Management Department
- Keep inventory records of chemicals using myLab system, and update regularly

4.4 Flammable liquid storage cabinets

Flammable chemicals should be stored inside flammable liquid storage cabinets. Only those flammables in use for the day should be outside the cabinet. Guidelines for cabinet use include:

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

4.5 Chemical compatibility

The storage scheme outlined in Section 4.6 below may not suffice to prevent mixing of incompatible chemicals. Certain hazardous combinations can occur even between chemicals of the same classifications.

Table 3 -*Examples of incompatible combinations of some commonly used chemicals*.

CHEMICAL	KEEP FROM CONTACT WITH:
Acetic Acid	chromic acid, nitric acid, hydroxyl compounds, perchloric acid, peroxides, permanganate
Acetylene	chlorine, bromine, copper, fluorine, silver, mercury
Alkali Metals (e.g. Sodium)	water, chlorinated hydrocarbons, carbon dioxide, halogens
Ammonia, Anhydrous	mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium Nitrate	acids, metal powders, flammable liquids, chlorates, nitrites, sulphur, finely divided combustible materials
Aniline	nitric acid, hydrogen peroxide
Bromine	same as chlorine
Carbon, Activated	calcium hypochlorite, all oxidizing agents
Chlorates	ammonium salts, acids, metal powders, sulphur, finely divided combustible materials
Chromic Acid	acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids
Chlorine	ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Copper	acetylene, hydrogen peroxide
Flammable Liquids	ammonium nitrate, inorganic acids, hydrogen peroxide, sodium peroxide, halogens, oxidizing agents
Hydrocarbons	fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrofluoric Acid	anhydrous ammonia, ammonium hydroxide
Hydrogen Peroxide	copper, chromium, iron, most metals or their salts, alcohols, acetone, aniline, nitromethane, flammable liquids, oxidizing gases
Hydrogen Sulphide	fuming nitric acid, oxidizing gases
Iodine	acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	acetylene, fulminic acid, ammonia
Nitric Acid	acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulphide, flammable liquids, flammable gases
Oxalic Acid	silver, mercury
Perchloric Acid	acetic anhydride, bismuth and its alloys, organic materials
Potassium	carbon tetrachloride, carbon dioxide, water
Potassium Chlorate	sulphuric and other acids
Potassium Permanganate	glycerin, ethylene glycol, benzaldehyde, sulphuric acid
Silver	acetylene, oxalic acid, tartaric acid, ammonia compounds
Sodium Peroxide	alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulphide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural

Sulphuric Acid	potassium chlorate, potassium perchlorate, potassium permanganate (or compounds with similar light metals, such as sodium, lithium, etc.)

4.6 Chemical segregation

- Read the label carefully before storing a chemical. More detailed storage information is usually provided by the SDS (Safety Data Sheet).
- Ensure that incompatible chemicals are not stored in close proximity to each other. Separate the following types of chemicals from each other according to the segregation scheme in Table 3. Note that this is a simplified scheme and that in some instances chemicals of the same category may be incompatible.
- For more detailed information refer to the reactivity section of the Material Safety Data Sheet or a reference manual on reactive chemical hazards.

Table 4 -*Suggested Segregation for Chemical Storage*

FLAMMABLES	**NON-FLAMMABLE SOLVENTS**
• Store in grounded flammable liquid storage cabinet • Separate from oxidizing materials Examples: • Acetone • Ethanol • Glacial acetic acid	• Store in cabinet • Can be stored with flammable liquids • Separate from oxidizing materials Examples: • Carbon tetrachloride • Ethylene glycol • Mineral oil
ACIDS	**CAUSTICS**
• Store in cabinet of non-combustible material • Separate oxidizing acids from organic acids • Separate from caustics, cyanides, sulfides Examples: • Nitric acid • Hydrochloric acid • Sulphuric acid	• Store in dry area • Separate from acids Examples: • Ammonium hydroxide • Sodium hydroxide • Potassium hydroxide

WATER REACTIVE CHEMICALS	OXIDIZERS
• Store in cool, dry location • Separate from aqueous solutions • Protect from fire sprinkler water Examples: • Sodium • Potassium • Lithium	• Store in cabinet of non-combustible material • Separate from flammable and combustible materials Examples: • Sodium hypochlorite • Benzoyl peroxide • Potassium permanganate
NON-OXIDIZING COMPRESSED GASES • Store in well-ventilated area • separate physically from oxidizing compressed gases Examples: • Nitrogen • Hydrogen • Carbon Dioxide	**OXIDIZING COMPRESSED GASES** • Separate physically from flammable compressed gases Examples: • Oxygen • Chlorine • Nitrous oxide
NON-VOLATILE, NON-REACTIVE SOLIDS • Store in cabinets or open shelves with edge guards Examples: • Agar • Sodium chloride • Sodium bicarbonate	

4.7 Unstable chemicals

Many chemicals, most notably ethers (e.g., THF, dioxane, diethyl and isopropyl ether), are susceptible to decomposition resulting in explosive products. Ethers, liquid paraffins, and olefins form peroxides on exposure to air and light. Since most of these products have been packaged in an air atmosphere, peroxides can form even if the containers have not been opened.

- Discard unopened containers of ethers after one year
- Discard containers of ethers within six months of opening
- Never handle ethers beyond their expiry dates; **contact your local waste disposal coordinator to arrange to have the material stabilized and removed**

The following are common examples of compounds prone to peroxide formation:

- Cyclohexene
- Dicyclopentadiene
- Diethyl ether (ether)
- Dimethyl ether
- Dioxane
- Isopropyl ether
- Furan
- Tetrahydrofuran (THF)

The label and Safety Data Sheet (SDS) will also indicate if a chemical is unstable.

4.8 Explosive chemicals

Many chemicals are susceptible to rapid decomposition or explosion when subjected to forces such as being struck, vibrated, agitated or heated. Some become increasingly shock sensitive with age. Picric acid becomes shock sensitive and explosive if it dries out.

- Refer to the label and the Safety Data Sheet to determine if a chemical is explosive.
- Write the dates received and opened on all containers of explosive or shock-sensitive chemicals
- Inspect all such containers every month
- 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
- Wear appropriate personal protective equipment and perform experiments behind face shield.
- Work with small quantities.

The following are atomic groupings that are associated with the possibility of explosion:

acetylide	fulminate	nitroso
amine oxide	N-haloamine	nitro
azide	hypohalite	ozonide
chlorate	hydroperoxide	perchlorate
diazo	nitrate	peroxide
diazonium	nitrite	picrate

The following are common examples of materials known to be shock-sensitive and explosive:

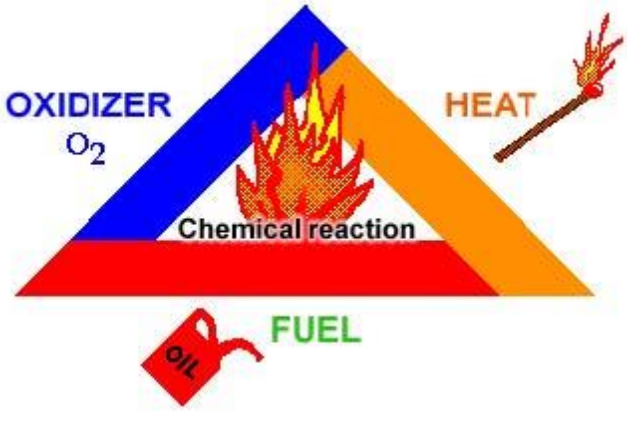
ammonium nitrate ammonium perchlorate copper acetylide dinitrotoluene	fulminate of mercury lead azide nitroglycerine picric acid (when dry) trinitrotoluene

5. Fire Safety

Laboratory fires can by caused by bunsen burners, runaway chemical reactions, electrical heating units, failure of unattended or defective equipment, or overloaded electrical circuits. Familiarize yourself with the operation of the fire extinguishers and the location of pull stations, emergency exits and evacuation routes where you work. In the event that the general alarm is sounded use the evacuation routes established for your area and follow the instructions of the Evacuation Monitors. Once outside of the building, move away from the doors to enable others to exit.

5.1 The fire triangle

Fire cannot occur without an ignition source, fuel and an oxidizing atmosphere (usually air), the three elements that comprise what is called the "fire triangle":



Fire will not be initiated if any one of these elements is absent, and will not be sustained if one of these elements is removed. This concept is useful in understanding prevention and control of fires. For example, the coexistence of flammable vapours and ignition sources should be avoided, but when flammable vapours cannot be controlled elimination of ignition sources is essential.

5.2 Classes of fire

The National Fire Protection Association (NFPA) has defined four classes of fire, according to the type of fuel involved. These are:

- *Class A* fires involve combustibles such as paper, wood, cloth, rubber and many plastics.

- *Class B* fires entail burning of liquid fuels like oil-based paints, greases, solvents, oil and gasoline.
- *Class C* fires are of electrical origin (fuse boxes, electric motors, wiring).
- *Class D* fires encompass combustible metals such as magnesium, sodium, potassium and phosphorus.

5.3 Fire extinguishers

Fire extinguishers are rated as A, B, C or D (or combinations of A, B, C and D) for use against the different classes of fires. Familiarize yourself with the fire class ratings of the extinguishers in your work area so that you will know what types of fire you can attempt to extinguish with them.

Learn how to use the extinguisher in your lab, as there will be no time to read instructions during an emergency. Attempt to fight small fires only, and only if there is an escape route behind you. After an extinguisher has been used, you must report it to Security Services. A patroller will be sent to obtain the extinguisher and will notify the Fire Prevention Office. If you do fight a fire, remember the acronym "PASS" when using the extinguisher:

- **P**: Pull and twist the locking pin to break the seal.
- **A**: Aim low, and point the nozzle at the base of the fire.
- **S**: Squeeze the handle to release the extinguishing agent.
- **S**: Sweep from side to side until the fire is out.

Be prepared to repeat the process if the fire breaks out again

5.4 Preventing fires

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.

- Minimize the quantities of flammable liquids kept in the laboratory.
- Do not exceed the maximum container sizes specified by the National Fire Protection Association (NFPA), as listed in Appendix 1.
- Except for the quantities needed for the work at hand, keep all flammable liquids in NFPA- or UL- (Underwriter's Laboratories) approved flammable liquid storage cabinets. Keep cabinet doors closed and latched at all times. Do not store other materials in these cabinets.
- Use and store flammable liquids and gases only in well-ventilated areas. Use a fume hood when working with products that release flammable vapours.
- Keep flammable solvent containers, including those for collecting waste, well capped. Place open reservoirs or collection vessels for organic procedures like HPLC inside vented chambers.
- Store flammable chemicals that require refrigeration in "explosion-safe" (non-sparking) laboratory refrigerators.
- Keep flammable chemicals away from ignition sources, such as heat, sparks, flames and direct sunlight. Avoid welding or soldering in the vicinity of flammables.
- 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.

5.5 Evacuations

In the event that the general alarm is sounded, follow the evacuation routes established for your area; do not use the elevators. Follow the instructions of the Evacuation Monitors. Once outside the building, move away from the doors to allow others to exit.

6. Hazardous Waste Disposal

6.1 Waste minimization

In order to minimize the amount of hazardous waste presented for disposal, it is important to follow these guidelines:

- *Avoid overstocking*: one of the main sources of laboratory waste is surplus stock - the result of over buying. McGill has pricing arrangements with suppliers that have greatly reduced the benefits of purchasing chemicals in large volumes. Also, there is little need to store large quantities of chemicals, as orders are generally shipped the day after an order is received.
- *Do not accept donations of materials* that you don't plan to use. Many companies have traditionally unloaded unwanted reagents by donating them to laboratories, which eventually transfers the cost of disposal to the University.
- *Substitute hazardous experimental materials* for non-hazardous ones. For example, use aqueous-based, biodegradable scintillation fluids whenever possible.

6.2 Hazardous waste disposal guidelines

- Label all waste materials completely and legibly, using labels available from the ***Hazardous Waste Management (HWM, local 5066)***. Inadequately labeled containers will not be accepted.
- Package waste materials in approved containers, available from HWM.
- Over filled and/or leaking containers cannot be accepted for disposal.
- Never discharge wastes into the sewer unless you have verified that hazardous wastes regulations permit you to do so. For information, contact HWM.

6.3 Waste preparation procedures

6.3.1 Chemical waste

6.3.1.1 Organic solvents and oils

- Collect in the containers provided by the ***Hazardous Waste Management (HWM, local 5066)***.
- Indicate the composition of the contents as accurately as possible on the attached label.

6.3.1.2 Expired/obsolete chemicals in their original containers (lab-packs)

- Expired chemicals are collected, packaged, and transported using steel drums (lab-pack).
- To request a pickup, please use the myLab software.

6.3.1.3 Chemicals of unknown composition

- Unknown chemicals cannot be accepted.

- Analyze or contact HWM to arrange for analysis (at the expense of the waste generator).

6.3.1.4 Peroxide-forming (e.g. ether) and explosive (e.g. dry picric acid) chemicals

- Do not mix with solvents or other waste.
- If the material is older than one year, do not attempt to open or move the container. Contact HWM for advice.

6.3.1.5. Corrosives (acids and bases)

- Collect acids (pH<7) and bases (pH>7) separately in the plastic containers provided by HWM. Do not mix acids with bases.
- DO NOT USE FOR CONCENTRATED MATERIAL or as a dilution vessel
- The waste container is to be used for spent solutions only. Never pour chemicals directly from their original containers; Hazardous Waste Management will pick those up in their original bottles.
- Indicate the composition of the contents, as accurately as possible, on the attached label.

6.3.2 Biomedical waste

6.3.2.1 Animal carcasses

- Place in the plastic-lined biomedical waste containers provided by the ***Hazardous Waste Management (HWM, local 5066)***
- Ensure that the weight of individual containers does not exceed 40 pounds.
- Store in a refrigerated area.

6.3.2.2 Infectious laboratory waste

- Place in the plastic-lined biohazard box provided by HWM.

6.3.2.3 Biohazardous sharps and pipette tips

- Refer to Section 6.3.3.1 below for further details.

6.3.2.4 Blood and blood-contaminated materials

- Unclotted blood can be disposed of via the sanitary drains. Designate one sink for this purpose.
- After discharging blood, decontaminate the sink with a 5-10% dilution of household bleach. Allow a contact time of 20 minutes, then rinse with water.
- Dispose of blood-contaminated materials as infectious laboratory waste.

6.3.3 Sharps, glass bottles and pipette tips

6.3.3.1 Sharps (blades and needles ONLY)

6.3.3.1.1 Contaminated sharps

- Label a plastic puncture proof container with the word "SHARPS", the appropriate hazard warning symbol (e.g. biohazard, radioactive) and the name of the Principal Investigator.
- Discard containers of sharps contaminated with infectious materials into biomedical waste containers as per the procedure for Infectious Laboratory Waste (Section 6.3.2.2) or autoclave container and use “non-contaminated sharps” procedure below

- Discard containers of sharps contaminated with radioactive materials as per the procedure for solid radioactive waste (Section 6.3.4)

6.3.3.1.2 Non-contaminated sharps

- Label a plastic puncture-proof container with the word "SHARPS", and the name of the Principal Investigator. Make sure there is no biohazard symbol on the container.
- Accumulate in the designated container, without overfilling.
- Place container in an "autoclaved waste box" and bring it to your hazardous waste room. If your building does not have a waste room, call 5066 for a pick-up.
- McGill's waste disposal service provider is using the same procedure to dispose of autoclaved waste and non-contaminated sharps waste, hence the reason why we are using that box for both waste streams.

6.3.3.2 Broken glassware and pipette tips

Broken glass and tips present a danger and must be packaged carefully.

- Find a regular but sturdy cardboard box or plastic pail;
- Label properly (“broken glass” and/or “pipette tips”)
- First place an absorbent pad on the bottom if the glass material is wet;
- Place your broken glass and pipettes tips inside;
- Seal box / bag / pail using tape;

6.3.3.2.1 Contaminated broken glassware / pipette tips

- Autoclave container & write "broken glass / pipette tips / garbage" on the cover and place the container next to the garbage bin **OR**
- Place container inside a biohazard box for incineration

6.3.3.2.2. Not-contaminated broken glassware / pipette tips

- Write "broken glass / pipette tips / garbage" on the cover and place next to garbage container.

6.3.3.3 Empty chemical reagent bottles

Used chemical bottles which are empty can be disposed via regular garbage. However, make sure that the bottle is clean. **Bottles and glass containers which were used to contain or hold chemicals must not be offered for recycling.**

- Remove the cap from the empty bottle and allow volatile materials to evaporate into the fume hood.
- Rinse the bottle three times with tap water and let dry.
- Remove / obliterate the label or write “rinsed bottle” on the label.
- Place the uncapped bottle next to the garbage receptacle.
- Contact ***Hazardous Waste Management (HWM, local 5066)***.

6.3.4 Radioactive waste

There are different types of radioactive waste that can be generated by the researchers:

- Solid waste (except sealed sources)

- Sealed and encapsulated sources
- Liquid scintillation vials
- Liquid radioactive waste

Please visit the Hazardous Waste Management website for detailed information on how to prepare the radioactive waste for disposal

7. Laboratory Ventilation & Fume Hoods

7.1 General ventilation

General ventilation, also called dilution ventilation, involves dilution of inside air with fresh outside air, and is used to:

- maintain comfortable temperature, humidity and air movement for room occupants
- dilute indoor air contaminants
- replace air as it is exhausted to the outside via local ventilation devices such as fume hoods
- provide a controlled environment for specialized areas such as surgery or computer rooms

General ventilation systems comprise an air supply and an air exhaust. The air may be supplied via a central HVAC (Heating, Ventilation and Air Conditioning) system or, especially in older buildings, via openable windows. Laboratory air may be exhausted through either local exhaust devices or air returns connected to the HVAC system.

7.2 Local ventilation devices

Local exhaust ventilation systems capture and discharge air contaminants (biological, chemical, radioactive) or heat from points of release. Common local exhaust ventilation devices found in laboratories include:

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

7.2.1 Chemical fume hoods

Chemical fume hoods are enclosed units with a sliding sash for opening or closing the hood. They are able to capture and exhaust even heavy vapours, and are preferred for all laboratory procedures that require manual handling of hazardous chemical material. Refer to Section 7.4 below for information on the safe use of chemical fume hoods.

7.2.2 Canopy hoods

Canopy hoods are designed to capture heat from processes or equipment, such as atomic absorption spectrophotometers or autoclaves; a canopy or bonnet is suspended over a process and connected to an exhaust vent. The following limitations make canopy hoods poor substitutes for chemical fume

hoods, because they:

- draw contaminated air through the user's breathing zone
- do not capture heavy vapours
- provide less containment than chemical fume hoods, and are more affected by air turbulence
- do not provide adequate suction more than a few inches away from the hood opening

7.2.3 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.

7.2.4 Biological safety cabinets

Biological safety cabinets are for use with biological material; depending on the cabinet class, they provide protection of the environment, user and/or product. They are not recommended for use with hazardous chemicals because most models recirculate air into the laboratory, and because the HEPA filter that is integral to the protective function can be damaged by some chemicals. Biological safety cabinets are described in more detail in the McGill Biosafety Manual.

7.2.5 Direct connections

Direct connections provide direct exhausting of contaminants to the outdoors and are used for venting:

- flammable liquid storage cabinets
- other toxic chemical storage cabinets
- solvent and waste reservoirs, such as for HPLC solvent systems
- reaction vessels, sample analyzers, ovens, dryers and vacuum pump outlets

7.3 Ventilation balancing and containment

By regulation, more air is exhausted from a laboratory than is supplied to it, resulting in a net negative pressure (vacuum) in the laboratory. Negative pressure draws air into the laboratory from surrounding areas, and serves to prevent airborne hazardous chemicals, radiation 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. Modern laboratories do not have openable windows, as opening of windows tends to pressurize a room, pushing air from the laboratory into adjacent non-laboratory areas.

7.4 Safe use of chemical fume hoods

Fume hoods properly used and maintained, will render substantial protection, provided the user is aware of its capabilities and limitations. The performance standard for fume hoods is the delivery of a minimum face velocity of 100 linear feet per minute at half sash height. An anemometer for determining a fume hood's face velocity is available from Environmental Health and Safety. To ensure your fume hood provides the highest degree of protection observe the following guidelines:

1. Only materials being used in an ongoing experiment should be kept in the fume hood. Cluttering the hood will create air flow disturbances.
2. When it is necessary to keep a large apparatus inside a hood, it should be placed upon blocks or legs to allow air to flow underneath.
3. Operate the hood with the sash as low as practical. Reducing the open face will increase the face velocity.
4. Work as far into the hood as possible. At least six inches is recommended.
5. Do not lean into the hood. This disturbs the air flow, and also places your head into the contaminated air inside the hood.
6. Do not make quick motions into or out of the hood, or create cross drafts by walking rapidly past the hood. Opening doors or windows can sometimes cause strong air currents which will disturb the air flow into the hood.
7. Heating devices should be placed at the rear of the hood.
8. Do not use a hood for any function it was not specifically designed, such as perchloric acid, some radioisotopes, etc.
9. Keep hood door closed when not attended.
10. Remember that sinks inside fume hoods are not designed for disposing of chemical wastes.

8. Compressed Gases and Cryogenics

8.1 Hazards of compressed gases

Compressed gases are hazardous due to the high pressure inside cylinders. Knocking over an unsecured, uncapped cylinder of compressed gas can break the cylinder valve; the resulting rapid escape of high pressure gas can turn a cylinder into an uncontrolled rocket or pinwheel, causing serious injury and damage. Poorly controlled release of compressed gas in the laboratory can burst reaction vessels, cause leaks in equipment and hoses or result in runaway chemical reactions. Compressed gases may also have flammable, oxidizing, dangerously reactive, corrosive or toxic properties. Inert gases such as nitrogen, argon, helium and neon can displace air, reducing oxygen levels in poorly ventilated areas and causing asphyxiation.

8.2 Safe handling, storage and transport of compressed gas cylinders

- All gas cylinders, full or empty, should be securely supported using suitable racks, straps, chains or stands.
- When cylinders are not in use or are being transported, remove the regulator and attach the protective cap.
- An appropriate cylinder cart should be used for transporting cylinders. Chain or strap the cylinder to the cart.
- Verify that the regulator is appropriate for the gas being used and the pressure being delivered. Do not rely upon the pressure gauge to indicate the maximum pressure ratings; check the regulator's specifications.
- Do not use adaptors or Teflon tape to attach regulators to gas cylinders.
- Never bleed a cylinder completely empty; leave a residual pressure.
- Do not lubricate the high-pressure side of an oxygen regulator.
- Do not expose cylinders to temperature extremes.
- Store incompatible classes of gases separately.

8.3 Cryogenic fluids and solids (dry ice) hazards

Cryogenics are very low temperature materials such as dry ice (solid CO2) and liquefied air or gases like nitrogen, oxygen, helium, argon and neon. The following hazards are associated with the use of cryogenics:

- asphyxiation due to displacement of oxygen (does not apply to liquid air and oxygen)
- embrittlement of materials from extreme cold
- frostbite
- explosion due to pressure build up
- condensation of oxygen and fuel (e.g. hydrogen and hydrocarbons) resulting in explosive mixtures

8.4 Cryogenic handling precautions

The following are precautions for handling cryogenics:

- Control ice build up
- Use only low-pressure containers equipped with pressure-relief devices.
- Protect skin and eyes from contact; wear eye protection and insulated gloves.
- Use and store in well-ventilated areas.
- Do not store in confined rooms, vapour can displace oxygen, leading to an oxygen deficient environment.
- Storage areas should be clean and dry.
- Keep away from sparks or flames (for flammables / oxidizers, i.e. liquid hydrogen, liquid oxygen).
- Incompatible materials must be avoided with cryogenics including dry ice; some metals (i.e. carbon steel) may fracture easily at low temperature.
- Do not store dry ice in tight containers during shipping which can lead to pressure build-up and potential explosive hazard.
- The dry ice should be stored in insulated containers that open from the top. Lids should fit loosely so that the cryogenic given off can escape into the atmosphere.
- Use materials resistant to embrittlement (e.g. latex rubber tubing).
- Watches, rings, bracelets or other jewelry that could trap fluids against flesh should not be worn when handling cryogenic liquids
- To prevent thermal expansion of contents and rupture of the vessel, do not fill containers to more than 80% of capacity.
- If cryogens must be transported by elevator, take adequate precautions to prevent possible injury. Send cryogenic liquid tanks in elevators without any passengers and ensure that nobody gets on the elevator while the cryogen is being transported.
- Carbon dioxide gas is about 1 ½ times as heavy as air and will accumulate in low-lying areas, so ventilation must be adequate at floor or below grade level.
- Never allow any unprotected parts of your body to touch uninsulated pipes or vessels containing cryogenics. This can lead to frostbite.

9. Physical Hazards and Ergonomics

9.1 Electrical safety

- Purchase and use only CSA-approved electrical equipment.
- 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.
- All electrical equipment (except glass-cloth heaters and certain models of oscillographs requiring a floating ground) should be wired with a grounding plug.
- All wiring should be done by, or under the approval of, a licensed electrician.
- Electrical equipment that has been wetted should be disconnected at the main switch or breaker before being handled. Familiarize yourself with the location of such devices.
- 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.
- Ensure that all wires are dry before plugging into circuits.
- Electrical equipment with frayed wires should be repaired before being put into operation.
- Tag and disconnect defective equipment.
- Be sure that all electrical potential has been discharged before commencing repair work on any equipment containing high voltage power supplies or capacitors.
- Minimize the use of extension cords and avoid placing them across areas of pedestrian traffic.
- Use only CO2, halon, or dry chemical fire extinguishers for electrical fires.
- Use ground fault circuit interrupters for all electrical equipment used for administering electrical current to human subjects or measuring electrical signals from human subjects.

9.2 High pressure and vacuum work

Pressure differences between equipment and the atmosphere result in many lab accidents. Glass vessels under vacuum or pressure can implode or explode, resulting in cuts from projectiles and splashes to the skin and eyes. Glass can rupture even under small pressure differences. Rapid temperature changes, such as those that occur when removing containers from liquid cryogenics, can lead to pressure differences, as can carrying out chemical reactions inside sealed containers.

The hazards associated with pressure work can be reduced by:

- checking for flaws such as cracks, scratches and etching marks before using vacuum apparatus
- using vessels specifically designed for vacuum work. Thin-walled or round-bottomed flasks larger than 1 L should never be evacuated
- assembling vacuum apparatus so as to avoid strain. Heavy apparatus should be supported from below as well as by the neck
- taping glass vacuum apparatus to minimize projectiles due to implosion
- using adequate shielding when conducting pressure and vacuum operations
- allowing pressure to return to atmospheric before opening vacuum desiccators or after removal

of a sample container from cryogenics

- wearing eye and face protection when handling vacuum or pressure apparatus

9.3 Repetitive work and ergonomics

Ergonomics is concerned with how the workplace "fits" the worker. Performing certain work tasks without regard for ergonomic principles can result in:

- fatigue
- repetitive motion injuries
- strains, aches and injuries from biomechanical stresses
- eyestrain from video display terminals (VDTs)
- decreased morale

Factors that can increase the risk of musculoskeletal injury are:

- awkward positions or movements
- repetitive movements
- application of force

In a laboratory setting, look for the following when addressing ergonomic concerns:

- Laboratory bench and workbench heights are suitable for all personnel
- Laboratory chairs are on wheels or castors, are sturdy (5-legged), and are adjustable (seat height, angle, backrest height)
- VDTs are positioned at or slightly below eye level, and are positioned so as to avoid glare from lights or windows
- Computer keyboards and pointing devices are positioned so that wrists are kept in a neutral position and forearms are horizontal
- Colour, lettering size and contrast of equipment display monitors are optimized so as not to cause eye strain
- Work station design does not necessitate excessive bending, reaching, stretching or twisting
- Vibration-producing equipment, such as vortex mixers and pump-type pipettors are not used for extended periods of time
- Buttons and knobs on equipment are accessible and of a good size
- Heavy items are not carried or handled
- Laboratory workers are using proper techniques when lifting or moving materials
- Indoor air quality parameters, such as temperature, humidity and air supply are comfortable
- Floors are slip-resistant
- Noise levels are not excessive

For an ergonomic workplace evaluation, please email EHS.

9.4 Glassware safety

- Use a dustpan and brush, not your hands, to pick up broken glass.
- Discard broken glass in a rigid container separate from regular garbage and label it appropriately (see Waste Preparation Procedures, Section 6.3).
- Protect glass that is subject to high pressure or vacuum. Wrapping glass vessels with cloth tape will minimize the possibility of projectiles.
- Glass is weakened by everyday stresses such as heating and bumping. Handle used glassware with extra care.
- Discard or repair all damaged glassware, as chipped, cracked or star-cracked vessels cannot handle the normal stresses.

When handling glass rods or tubes:

- fire polish the ends,
- lubricate with water or glycerine when inserting through stopper,
- ensure stopper holes are properly sized, and not too small,
- insert carefully, with a slight twisting motion, keeping hands close together, and
- use gloves or a cloth towel to protect your hands

10. Equipment Safety

Whenever lab equipment is purchased, preference should be given to equipment that

- limits contact between the operator and hazardous material, and mechanical and electrical energy
- is corrosion-resistant, easy to decontaminate and impermeable to liquids
- has no sharp edges or burrs
- Every effort should be made to prevent equipment from becoming contaminated.

To reduce the likelihood of equipment malfunction that could result in leakage, spill or unnecessary generation of aerosolized pathogens:

- Review the manufacturer's documentation. Keep for future reference.
- Use and service equipment according to the manufacturer's instructions.
- Ensure that anyone who uses a specific instrument or piece of equipment is properly trained in setup, use and cleaning of the item.
- Ensure that equipment leaving the laboratory for servicing or disposal is appropriately decontaminated. Complete a Certificate of Equipment Decontamination form and attach it to the equipment before it leaves the lab.

The following sections outline some of the precautions and procedures to be observed with some commonly used laboratory equipment.

10.1 Centrifuges

Improperly used or maintained centrifuges can present significant hazards to users. Failed mechanical parts can result in release of flying objects, hazardous chemicals and biohazardous aerosols. The high speed spins generated by centrifuges can create large amounts of aerosol if a spill, leak or tube breakage occurs. To avoid contaminating your centrifuge:

- Check glass and plastic centrifuge tubes for stress lines, hairline cracks and chipped rims before use. Use unbreakable tubes whenever possible.
- Avoid filling tubes to the rim.
- Use caps or stoppers on centrifuge tubes. Avoid using lightweight materials such as aluminum foil as caps.
- Use sealed centrifuge buckets (safety cups) or rotors that can be loaded and unloaded in a biological safety cabinet. Decontaminate the outside of the cups or buckets before and after centrifugation. Inspect o-rings regularly and replace if cracked or dry.
- Ensure that the centrifuge is properly balanced.
- Do not open the lid during or immediately after operation, attempt to stop a spinning rotor by hand or with an object, or interfere with the interlock safety device.
- Decant supernatants carefully and avoid vigorous shaking when re-suspending.

When using high-speed or ultra centrifuges, additional practices should include:

- Connect the vacuum pump exhaust to a trap.
- Record each run in a logbook: keep a record of speed and run time for each rotor.
- Install a HEPA filter between the centrifuge and the vacuum pump when working with biohazardous material.
- Never exceed the specified speed limitations of the rotor.

10.2 Electrophoresis equipment

- Ensure that electrophoresis equipment is properly grounded and has electrical interlocks. Do not bypass safety interlocks.

- Inspect electrophoresis equipment regularly for damage and potential tank leaks.
- Locate equipment away from high traffic areas, and away from wet areas such as sinks or washing apparatus.
- Display warning signs.

10.3 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°C. The following precautions are appropriate for heating baths:

- set up on a stable surface, away from flammable and combustible materials including wood and

paper

- relocate only after the liquid inside has cooled
- ensure baths are equipped with redundant heat controls or automatic cut-offs that will turn off the power if the temperature exceeds a pre-set limit
- use with the thermostat set well below the flash point of the heating liquid in use
- equip with a thermometer to allow a visual check of the bath temperature.

The most common heating bath used in laboratories is the water bath. When using a water bath:

- clean regularly; a disinfectant, such as a phenolic detergent, can be added to the water
- avoid using sodium azide to prevent growth of microorganisms; sodium azide forms explosive compounds with some metals
- raise the temperature to 90ºC or higher for 30 minutes once a week for decontamination purposes
- unplug the unit before filling or emptying, and have the continuity-to-ground checked regularly

10.4 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
- immersing the tip deeply enough into the solution to avoid creation of aerosols when using a sonicator
- decontaminating exposed surfaces after use

10.5 Ovens and hot plates

Laboratory ovens are useful for baking or curing material, off-gassing, dehydrating samples and drying glassware.

- Select and purchase an oven whose design prevents contact between flammable vapours and heating elements or spark-producing components
- Discontinue use of any oven whose backup thermostat, pilot light or temperature controller has failed
- Avoid heating toxic materials in an oven unless it is vented outdoors (via a canopy hood, for example)
- Never use laboratory ovens for preparation of food for human consumption

- Glassware that has been rinsed with an organic solvent should be rinsed with distilled water before it is placed in a drying oven

10.6 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.
- Wear safety glasses and lab coats (and other appropriate personal protective equipment as specified) for all procedures.

10.6.1 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.

10.6.2 Atomic absorption (AA) spectrometers

Sample preparation for atomic absorption procedures often require 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.

10.6.3 Mass spectrometers (MS)

Mass spectrometry requires the handling of compressed gases and flammable and toxic chemicals.

Consult SDSs 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, 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.

10.6.4 Gas chromatographs (GC)

Gas chromatography requires handling compressed gases (nitrogen, hydrogen, argon, helium), and flammable and toxic chemicals. Consult product SDSs before using such hazardous products. Specific precautions for working with gas chromatographs include:

- Perform periodic visual inspections and pressure leak tests of the sampling system plumbing, fittings and valves.
- Follow the manufacturer's instructions when installing columns. Glass or fused capillary columns are fragile: handle them with care and wear safety glasses to protect eyes from flying particles while handling, cutting or installing capillary columns.
- Turn off and allow heated areas such as the oven, inlet and detector, as well as connected hardware, to cool down before touching them.
- To avoid electrical shock, turn off the instrument and disconnect the power cord at its receptacle whenever the access panel is removed.
- Turn off the hydrogen gas supply at its source when changing columns or servicing the instrument.
- 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.
- Measure hydrogen gas and air separately when determining gas flow rates.
- Perform a radioactive leak test (wipe test) on electron capture detectors (ECDs) at least every 6 months for sources of 50MBq (1.35 mCi) or greater.
- Ensure that the exhaust from (ECDs) is vented to the outside.
- When performing split sampling, connect the split vent to an exhaust ventilation system or appropriate chemical trap if toxic materials are analyzed or hydrogen is used as the carrier gas.
- Use only helium or nitrogen gas, never hydrogen, to condition a chemical trap.

10.6.5 Nuclear magnetic resonance (NMR) equipment

The superconducting magnet of NMR equipment produces strong magnetic and electromagnetic fields that can interfere with the function of cardiac pacemakers. Users of pacemakers and other implanted ferromagnetic medical devices are advised to consult with their physician, the pacemaker's manual and pacemaker manufacturer before entering facilities which house NMR equipment. Precautions for work with NMR include the following:

- Post clearly visible warning signs in areas with strong magnetic fields.

- Measure stray fields with a gauss meter, and restrict public access to areas of 5-gauss or higher.
- The strong magnetic field can suddenly pull nearby unrestrained magnetic objects into the magnet with considerable force. Keep all tools, equipment and personal items containing ferromagnetic material (e.g., steel, iron) at least 2 meters away from the magnet.
- Though not a safety issue, advise users that the magnetic field can erase magnetic media such as tapes and floppy disks, disable credit and automated teller machine (ATM) cards, and damage analog watches.
- Avoid skin contact with cryogenic (liquid) helium and nitrogen; wear a protective face mask and loose-fitting thermal gloves during dewar servicing and when handling frozen samples. Refer to Section 11.
- Ensure that ventilation is sufficient to remove the helium or nitrogen gas exhausted by the instrument.
- Avoid positioning your head over the helium and nitrogen exit tubes.
- NMR tubes are thin-walled; handle them carefully and reserve them for NMR use only.

10.6.6 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 SDSs.

- 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 autoignition 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.
- Shut down and allow the system to return to atmospheric pressure before carrying out maintenance procedures.

10.6.7 Liquid chromatography (LC/MS) equipment

LC/MS requires the handling of compressed nitrogen and flammable and toxic chemicals. Consult product SDSs 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.

11. Personal Protective Equipment

The University's policies regarding eye and face protection (Section 11.1) and protective clothing (Section 11.2) are outlined below. Note that hazardous materials include those defined by WHMIS legislation as "hazardous products", as well as open radioactive sources as defined by Canadian Nuclear Safety Commission legislation.

11.1 Eye and face protection

All students, staff, faculty and visitors must wear appropriate eye and/or facial protection (safety glasses and/or face shield) in the following:

- All areas where hazardous materials, or substances of an unknown nature, are stored, used or handled
- All areas where the possibility of splash, flying objects, moving particles and/or rupture exist
- All areas where there are other eye hazards, e.g. UV or laser light

Instructions for selection and use of protective eyewear are as follows:

- Light-to-moderate work: CSA approved safety glasses with side shields.
- Work with significant risk of splash of chemicals, or projectiles: goggles.
- Work with significant risk of splash on face, or possible explosion: full face shield, plus goggles.
- If safety glasses with correction lenses are needed, first consult with your optometrist or ophthalmologist.

11.2 Lab coats

Appropriate protective clothing (e.g., lab coats, aprons, coveralls) is required in all experimental areas where hazardous materials are handled.

Instructions for selection and use of protective laboratory clothing are as follows:

- select knee-length lab coats with button or snap closures
- wear a solid-front lab coat or gown with back closures and knitted cuffs when working with highly toxic or infectious agents
- wear protective aprons for special procedures such as transferring large volumes of corrosive material
- remove protective clothing when leaving the laboratory
- remove protective clothing in the event of visible or suspected contamination

11.3 Hand protection

In the laboratory, gloves are used for protection from radiation, chemical products, biohazardous material and physical hazards such as abrasion, tearing, puncture and exposure to temperature extremes

11.3.1 Latex gloves and skin reactions

Natural latex is derived from the sap of the rubber tree and contains rubber polymers, carbohydrates,

lipids, phospholipids and proteins. During the manufacturing process additional chemical agents are added to impart elasticity, flexibility and durability to the latex. Because of these properties, and because of their high tactile strength and low cost, latex gloves are used for many laboratory procedures. Unfortunately, for some people, wearing latex gloves can cause skin reactions; these can be either irritant or allergic in nature, and can be caused by:

- chronic irritation from sweating of hands inside gloves or from gloves rubbing against the skin
- sensitization to the chemical additives used in the manufacturing process
- reaction to naturally-occurring latex proteins

Frequent handwashing, as well as residues from scrubs, soaps, cleaning agents and disinfectants may further irritate the skin.

Using one of the following alternatives may reduce the risk of skin problems associated with the use of latex rubber gloves:

- non-latex gloves
- "hypo-allergenic", non-powdered or low-protein latex gloves
- polyethylene, PVC or cloth liners under latex gloves
- non-latex gloves under latex gloves

Occurrences of skin problems (e.g., rash, itching, peeling, red, blistering skin or dry flaking skin with cracks and sores) that seem to be associated with the wearing of latex gloves should be reported to a physician when symptoms first appear.

11.3.2 Glove selection guidelines

Base selection of glove material on:

- identification of the 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 (e.g., occasional or splash vs. prolonged or immersion contact)
- whether disposable or reusable gloves are more appropriate

Table 5 -*Recommended glove materials for a variety of laboratory hazards*

Trademark names were included because the reader is likely to encounter them in the literature: consult laboratory or safety equipment suppliers, or the manufacturer, for more information on brand name gloves. Gloves not listed here may also be suitable; refer to the SDS, glove manufacturer or permeation chart. The section on electricity is included for information purposes only, as all electrical work must be done by licensed electricians.

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, biohazardous products, radioactive products (general lab work	Varies depending on the concentration, contact time, etc. Consult SDS, 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 350oC	Asbestos Zetex™
	Up to 350oC	Neoprene-coated asbestos, heat-resistant leather with linings, Nomex, Kevlar™
	Up to 200oC	Heat-resistant leather, terry cloth (aramid fibre), Nomex, Kevlar™
	Up to 100oC	Chrome-tanned leather, terry cloth
Electricity	Rubber-insulated gloves tested to appropriate voltage (CSA Standard Z259.4-M1979) with leather outer glove	
General duty	Cotton, terry cloth, leather	
Product contamination	Thin-film plastic; lightweight leather, cotton, polyester, nylon	

11.3.3 Chemical glove selection

No single glove material is resistant to all chemicals, nor will most gloves remain resistant to a specific chemical for longer than a few hours. Determine which gloves will provide an acceptable degree of resistance by consulting the SDS for the product, contacting glove manufacturers or by referring to a compatibility chart or table for permeation data. These resources may use the following terms:

- "permeation rate" refers to how quickly the chemical seeps through the intact material: the higher the permeation rate the faster the chemical will permeate the material;

- "breakthrough time" refers to how long it takes the chemical to seep through to the other side of the material, and
- "degradation" is a measure of the physical deterioration (for example, glove material may actually dissolve or become harder, softer or weaker) following contact with the chemical

11.3.4 Selection, use and care of protective gloves

Guidelines for glove use include the following:

- choose a glove that provides adequate protection from the specific hazard(s)
- be aware that some glove materials may cause adverse skin reactions in some individuals and investigate alternatives
- inspect gloves for leakage before using; test rubber and synthetic gloves by inflating them
- make sure that the gloves fit properly
- ensure that the gloves are long enough to cover the skin between the top of the glove and the sleeve of the lab coat
- discard worn or torn gloves
- discard disposable gloves that are, or may have become, contaminated
- avoid contaminating "clean" equipment: remove gloves and wash hands before carrying out tasks such as using the telephone
- always wash your hands after removing gloves, even if they appear not to be contaminated
- do not reuse disposable gloves
- follow the manufacturer's instructions for cleaning and maintenance of reusable gloves
- before using gloves, learn how to remove them without touching the contaminated outer surface with your hands

11.4 Respirators

Respirators should be used only in emergency situations (e.g. hazardous spills or leaks) or when other measures, such as ventilation, cannot adequately control exposures.

There are two classes of respirators: air-purifying and supplied-air. The latter supply clean air from a compressed air tank or through an airline outside the work area, and are used in oxygen-deficient atmospheres or when gases or vapours with poor warning properties are present in dangerous concentrations.

Air-purifying respirators are suitable for many laboratory applications and remove particulates (dusts, mists, metal fumes etc.) or gases and vapours from the surrounding air.

11.4.1 Selection, use and care of respirators

Follow proper procedures for selecting and using respiratory protective equipment. Correct use of a respirator is as vital as choosing the right respirator. An effective program for respiratory protection should include the following:

- written standard operating procedures and training

- selecting a respirator that is suitable for the application. Consult the SDS or the Environmental Health & Safety before purchasing and using a respirator
- assigning respirators to individuals for their exclusive use, whenever possible
- fit-testing: evaluation of facial fit for all users of respirators; beards, long sideburns, glasses or the wrong size of respirator may prevent an effective seal between the wearer's face and the respirator.
- protocols for using, cleaning and sanitary storage of respirators
- regular inspection of the respirator, and replacement of defective parts
- medical surveillance, before an individual is assigned to work in an area where respirators are required, to verify the person's ability to function under increased breathing resistance.

EHS provides fit testing for reusable and disposal masks (N95).

12. Emergency Procedures

12.1 First aid

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 the contents of the first aid kit and learn how to use them. Keep instructions readily available and easy to understand.
- Locate and know how to test and operate emergency equipment, such as emergency showers and eyewashes, in your area (Refer to Section 1.4).
- Learn first aid: Contact Environmental Health and Safety for a schedule of CNESST (Commission des normes, de l'équité, de la santé et de la sécurité du travail)-approved workplace first aid and CPR (cardiopulmonary resuscitation) course dates.

The emergency first aid procedures described below should be followed by a consultation with a physician for medical treatment.

12.1.1 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 in Section 12.1.4 below. In electrical burns, electrical current passing through the body generates heat.

12.1.1.1 Burns to the skin

First aid treatment of skin burns encompasses the following:

- If the burn is electrical in origin, ascertain that the victim is not in contact with the power supply before touching him/her. If the victim remains in contact with a power source, unplug the device or shut off the main power switch at the electrical distribution panel.

- Dial 911 if the burn is serious. Seek immediate medical treatment for all electrical burns, even if they don't appear to be serious.
- Remove jewelry, including watches, from the burned area.
- Expose the burnt area, but avoid removing clothes that are stuck to the skin.
- If possible, immerse burnt surfaces in cold water for at least 10 minutes, or apply cold wet packs.
- Avoid applying lotions, ointments or disinfectants to a burn. First and second degree burns can be washed with soap and water after the cool down period.
- Cover first and second degree burns with a moist bandage; apply dry compresses to third degree burns and to entry and exit wounds of electrical burns.
- Do not burst blisters, as they form a natural barrier against infection.

12.1.1.2 Burns to the eyes

Burns to the eyes may be caused by chemical substances, heat (hot liquids, steam, open flames, molten metal, etc.), or radiation from welding procedures, laboratory lamps and lasers. Burns caused by ultraviolet, visible or near-infrared radiation may not produce symptoms until 6-8 hours after exposure. First aid procedures for chemical burns to the eyes are described in Section 12.1.4 below. General first aid procedures for thermal and radiation burns to the eyes are as follows:

- Prevent the victim from rubbing or touching the eyes.
- For heat burns, flush the eyes with cool water until the pain subsides.
- Cover the eyes with dry sterile gauze pads; apply a wet compress to the eyes if it is too painful to close them.
- Send the victim for medical care. If the burn is the result of exposure to a laser beam, advise emergency medical personnel of the characteristics of the laser and the distance between the victim and the laser.

12.1.2 Cuts

First aid treatment for minor scrapes, scratches, cuts, lacerations or puncture wounds include the following:

- wash the wound and surrounding area with mild soap and running water
- remove any dirt around the wound
- cover with an adhesive dressing or gauze square taped on all sides with adhesive tape
- wounds caused by dirty, soiled or grimy objects should be examined by a physician, who will determine whether a tetanus immunization is needed
- if the wound was caused by an object that has contacted human blood or body fluids, the victim must be seen by a physician immediately, as immunization or post-exposure prophylaxis may be required.
- if a wound is bleeding profusely, the first aider should attempt to stop the bleeding as quickly as possible:
- elevate the injured area above the level of the heart, if possible, in order to reduce the blood pressure to the area of the wound.
- apply direct pressure to the wound unless an object is protruding from it (in this situation, apply

pressure around the injury). Direct pressure can be applied with the fingers of the hand, the palm of the hand or with a pressure dressing.

- if bleeding cannot be controlled with direct pressure, apply pressure to the arteries supplying the injured area. This involves compressing the artery between the wound and the heart, against a bone.
- do not remove a dressing that has become soaked with blood, as this may interrupt the clotting process; apply an additional dressing on top of the first.
- avoid over-tightening of the dressing; i.e., do not cut off the blood circulation to limbs.
- as a tourniquet completely stops the flow of blood to beyond the point of application, it should be applied only as a last resort, as in the case of a severed limb.

12.1.3 Needle stick injuries

Treat bleeding needle-related injuries as described in Section 12.1.2 above. Consult a physician immediately, as post-exposure prophylaxis or immunization may be required.

12.1.4 Chemical splashes to the skin or eyes

For splashes to the skin:

- If the splash affects a large area of skin, go to the nearest emergency shower and rinse thoroughly for at least 20 minutes; remove contaminated clothing while in the shower
- For splashes involving a small skin area, proceed to the nearest drench hose, remove contaminated clothing and jewelry and rinse for 15 minutes.

For splashes to the eyes:

- Go to the nearest eyewash station and rinse for at least 20 minutes.
- If you are wearing contact lenses, remove them as quickly as possible, while continuing to flush.
- Hold your eyelids open with your fingers.
- Roll your eyeballs, so that water can flow over the entire surface of the eye.
- Lift your eyelids frequently to ensure complete flushing.
- Cover the injured eye with dry sterile gauze pads while waiting for medical attention.

12.1.5 Poisoning

As described in Section 3.1, 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 Quebec Poison Control Centre (1-800-463-5060)
- Provide emergency medical personnel with the SDS 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 vomitus.

- Always ensure that the victim receives medical attention, even if the exposure seems minor.

12.2 Fires

The immediate response depends on the size of the fire. Laboratory personnel should attempt to extinguish a fire only if it is clearly safe to do so (Refer to Section 5.3).

12.2.1 Suspected fires

All members of the University should familiarize themselves with the locations of the fire alarms and evacuation routes in the areas that they occupy. Anyone discovering smoke, strong smell of burning or smell of an unusual nature, should immediately:

- Inform Security, local 3000 (local 7777 at Macdonald Campus).
- Alert the Building Emergency Warden, Building Service person or Building Director.

12.2.2 Known fires

- Shout "FIRE!" repeatedly to give the alert.
- Pull the fire alarm.
- Telephone the City Fire Department from a safe location by dialing 911.
- Evacuate the premises in a swift, orderly fashion using the stairways and/or fire escapes, but NOT the elevators, and following the instructions of Evacuation Monitors.
- Inform the Building Emergency Warden of the location, magnitude and nature (e.g. electrical) of the fire, the open evacuation routes, individuals requiring assistance, and other pertinent details.
- Once outside the building, move away from the doors to enable others to exit.

12.2.3 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 (refer to Section 12.1 above).

12.3 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:

- If there is fire, pull the nearest alarm. If you are unable to control or extinguish a fire, follow the fire evacuation procedures, as described in Section 5.5).
- 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 (Downtown 3000, Macdonald 7777) to request additional assistance if you cannot manage the clean-up yourself.
- 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 (Downtown 3000, Macdonald 7777), 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 Section 3.6.3 of this manual.

12.4 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.
- Call local 3000 (local 7777 at Macdonald campus) if the odour persists.
- Dial 911 if there is a confirmed gas leak.

12.5 Water Pressure Drops

In the event of a water pressure drop compromising the operation of emergency eyewashes or showers refrain from conducting any work involving hazardous materials until the water pressure is restored and contact Facilities Call Center (FCC) to report the problem by phone at 514- 398-4555 or by email).

Appendix 1: Flammability Classification and Permissible Container Sizes

(NFPA, Flammable and Combustible Liquids Code, 2003)

		Flash & Boiling point ranges **DegoC**	**Container type(L)**		
			Glass	**Metal or plastic**	**Safety can**
Flammable Liquids					
Class	**Example**				
1A	Acetaldehyde Ethyl Ether Pentane	FP <22.8 BP <37.8	0.5*	5	10
1B	Acetone Ethanol Toluene	FP <22.8 BP >37.8	1*	20	20
1C	Isobutanol Styrene	FP ≥22.8, <37.8	5	20	20
Combustible Liquids					
Class	**Example**				
II	Kerosene Acetic anhydride	FP ≥37.8, <60	5	20	20
IIIA	Aniline Octanol	FP ≥60, <93	20	20	20
IIIB	Ethylene Glycol Bnezyl alcohol	FP ≥93	20	20	20

*NFPA 6.2.3.2: Class 1A and Class 1B liquids shall be permitted to be stored in glass containers of not more than 5L (1.3 gal) capacity, if the required liquid purity (such as ACS analytical reagent grade or higer) would be affected by storage in metal containers or if the liquid can cause excessive corrosion of the metal container.

References

- Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNEEST), https://www.cnesst.gouv.qc.ca/

- Loi sur la santé et sécurité du travail (LSST), http://legisquebec.gouv.qc.ca/fr/showdoc/cs/s-2.1

- Health Canada, Hazardous Products Act, https://laws-lois.justice.gc.ca/eng/acts/h-3/

- Health Canada, Hazardous Products Regulation, https://laws-lois.justice.gc.ca/eng/regulations/SOR-2015-17/index.html

- The Canadian Centre for Occupational Health and Safety (CCOHS), https://www.ccohs.ca/