Safety, Health, Environment & Risk Management

LABORATORY SAFETY MANUAL

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The materials contained in this document have been compiled from sources believed to be reliable and to represent the best opinions on the subject. This document is intended to serve only as a starting point for good practices and does not purport to specify minimal legal standards. No warranty, guarantee, or representation is made by Laurier as to the accuracy or sufficiency of information contained herein, and Laurier assumes no responsibility in connection therewith. This document is intended to provide basic guidelines for safe practices. Therefore, it cannot be assumed that all necessary warning and precautionary measures are contained in this document and that other or additional information or measures may not be required. Users of this document should consult additional sources of safety information prior to undertaking specific tasks.

Acknowledgments

The following individuals of Laurier made important contributions to the writing, editing, and production of this manual: the faculty and staff of the Faculty of Science and Safety, Health, Environment & Risk Management (SHERM).

Laurier's Laboratory Health and Safety Manual's general forms and content were additionally shaped by similar manuals from The University of Guelph and the University of Western Ontario.

This manual was prepared for Laurier (2007) and revised in July 2012. Any corrections, additions or comments should be brought to the attention of the Chemical Safety Officer at 519-884-0710 ext. 3108.

Emergency Contact Information

911 or 9-911 from any campus phone

	Brantford	Waterloo
Special Constable Service	Market Place First Floor 45 Market Street **Ext. 5888 or 519-756-8228 ext. 5888**	Lower Level Student Services Building **Ext. 3333 or 519-885-3333**
Health Services	519-756-8228 ext. 5803	519-884-0710 ext. 3146
Physical Resources	519-756-8228 ext. 5761	519-884-0710 ext. 6280
Safety, Health, Environment & Risk Management (SHERM)	Chemical Safety Officer: 519-884-0710 ext. 3108 Director, SHERM: 519-884-0710 ext. 2874 Environmental/Occupational Health & Safety Advisor: 519-756-8228 ext. 5469	
Research Instrumentation Technician	519-884-0710 ext. 2361	

1. Objective

The objective of this manual is to provide information on health and safety policies and procedures and to define ***minimum*** standards for safe practices in the University's research and teaching laboratories.

2. Introduction

Scientists at Laurier conduct extensive research in the university's laboratories and provide valuable educational opportunities to many undergraduate and graduate students. However, while working in the laboratories, they are exposed to potential hazards unique to laboratory settings. To address the health, safety and environmental challenges specific to the laboratories, this manual and the enclosed guidelines and procedures have been developed.

3. Definitions

3.1 ACT

Occupational Health and Safety Act of Ontario

3.2 SUPERVISOR

A person who has charge of a workplace, or authority over a worker *(OH&S Act of Ont. Sec. 1(1)).* This includes faculty and staff, including TAs and IAs who supervise a laboratory. The laboratory supervisor is responsible for all those working in the laboratory (paid or unpaid, student, volunteer, or visitor) and must ensure the safety of all those who enter the lab.

3.3 COMPETENT PERSON

A person who:

a. Is qualified because of knowledge, training and experience to organize the work and its performance;
b. Is familiar with the Act and the regulations that apply to the work;
c. Has knowledge of any potential or actual danger to health or safety in the workplace *(OH&S Act of Ont. Sec. 1(1)).*

3.4 DUE DILIGENCE

Taking all precautions reasonable in the circumstance to protect the health and safety of a worker.

3.5 LABORATORY PERSONNEL

At Laurier, all individuals who perform procedures in a laboratory. Some of these individuals may have supervisory functions.

3.6 DEPARTMENT

An academic department, duly constituted by the Senate and Board of Governors (e.g., Department of Biology, Department of Physics & Computer Science).

3.7 LABORATORY

For the purposes of this manual any space where scientific research, experimentation or analysis is conducted. Computer "labs" are excluded from this definition.

3.8 TEACHING LABORATORY

A laboratory designed solely for the purpose of student instruction in the execution of experimental procedures associated with an approved academic course at Laurier.

3.9 RESEARCH LABORATORY

A laboratory designed to conduct research and to train individuals in advanced laboratory procedures and practice that may or may not be associated with an approved academic course at Laurier.

4. Supervisor's Responsibilities

The supervisor of the laboratory has overall responsibility for safety in the lab. It is recommended that regular monthly safety inspections be conducted by the supervisor, and that records of these inspections be kept on file.

In addition the supervisor is responsible for ensuring that:

a. All employees must be provided with appropriate safety orientation when they are assigned to a laboratory.

b. All laboratory workers attend the prescribed training sessions provided by SHERM.

c. All workers are aware of safety rules and procedures, that they follow them, and that they are aware of all emergency procedures and locations of emergency equipment.

d. Workers are familiarized with all hazards, including those associated with specific operating procedures. The employee must be made aware of these hazards before work begins.

e. Adequate emergency equipment is available and is in proper working order.

f. An Accident/Incident Report Form is filled out and sent to SHERM for every accident or incident that occurs in his/her laboratory.

g. That appropriate emergency information and cautionary signage is posted in the lab and updated regularly.

h. An appropriate alternate supervisor is appointed when the laboratory supervisor is absent.

5. Laboratory Personnel's Responsibilities

Every person working in a laboratory is responsible for ensuring that he or she:

a. Follows all applicable safety rules and practices outlined in this manual and by the laboratory supervisor.

b. Uses and wears personal protective equipment as required.

c. Reports unsafe equipment and working conditions to the laboratory supervisor.

d. Reports all accidents/incidents to the laboratory supervisor.

e. Completes all applicable health and safety training offered by SHERM and laboratory supervisor.

6. Training

It is the responsibility of the laboratory supervisor to ensure that:

a. All laboratory personnel have received adequate training in the use of specific equipment, and regarding the materials and procedures in the laboratory in which they will be working.

b. All training is documented, and documentation is maintained for all personnel throughout the employment of the employee.

In addition to project-specific training, the supervisor must ensure that all personnel are made aware of safety and emergency procedures, including but not limited to emergency evacuation routes, emergency or safety procedures specific to the individual laboratory, and procedures included in this manual and in Laurier's health and safety policies. Supervisors must ensure that all laboratory personnel have successfully completed all applicable courses prescribed in the SHERM Training Matrix **prior to** beginning work in the lab. See the SHERM website at www.wlu.ca/sherm to view the training requirements.

7. Workplace Hazardous Materials Information System (WHMIS)

The Workplace Hazardous Materials Information System (WHMIS) is a legislated program that applies to all Laurier faculty, staff and students. WHMIS has been developed as a tool to help employers and employees protect their health and safety. WHMIS ensures that information passes from the producer or supplier of a hazardous material to the employer and from the employer to the employee. This transfer involves three mechanisms: the use of warning labels, Material Safety Data Sheets (MSDSs) and training on how to use the information provided.

7.1 LABELS

The label is the primary source of hazard information. The requirements for label content depend on whether containers have come from a supplier or a workplace and whether the hazardous material is a laboratory product, a sample for analysis, or neither.

7.1.1 Supplier Labels

Supplier labels for containers with 100 mL or more of hazardous material must include the following information in both English and French enclosed by a distinctive border coloured to contrast with the background of the label:

- Product identifier or name
- Supplier identifier (supplier's name)
- Reference to the MSDS
- Hazard symbol(s)
- Risk phrase(s) (description of the main hazards of the product)
- Precautionary measures
- First aid measures

Supplier labels for hazardous materials in a container with less than 100 mL do not require risk phrases, precautionary measures, or first aid measures.

7.1.2 Workplace Labels

A label generated in the workplace must contain the following information:

- Product identifier or name
- Precautionary measures
- Reference to the MSDS

7.1.3 Laboratory Labels

For hazardous materials originating from a laboratory supply house that are to be used solely in a laboratory and that are supplied in quantities less than 10 kg, a laboratory label is permitted, and must contain the following information:

- Product name or identifier
- Risk phrases
- Reference to MSDS
- Precautionary measures
- First aid measures

Hazardous materials transferred to a container other than the original, for use only in the laboratory where the transfer took place; need to be labelled with the product identifier only.

In the case of hazardous materials for lab analysis, where containers hold less than 10 kg, the label must include the following information:

- Product identifier
- Chemical or generic name of any hazardous ingredient
- Name of the person submitting the sample
- Emergency telephone number of the submitter
- The statement "Hazardous Laboratory Sample”

Samples prepared for analysis in the laboratory where the analysis will take place, that remain under the control of the researcher producing the sample, and that will remain in the laboratory where produced, need to be labelled with the product identifier only.

7.2 MATERIAL SAFETY DATA SHEETS (MSDSs)

MSDSs provide detailed information about physical, chemical and toxicological properties and hazards, and recommended handling and emergency procedures. MSDSs must be reviewed and/or revised by the supplier or manufacturer at least every three years. Up to date MSDSs must be readily available for all controlled products on site.

7.2.1 Toxicological Properties: LD_{50} and LC_{50}

Exposure to hazardous materials can occur by:

- Absorption
- Ingestion
- Inhalation
- Injection

LD_{50} and LC_{50} values are commonly used measurements for the toxicity of a substance.

LD_{50} (Lethal $Dose_{50}$) is the amount of a pure 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% of a population. The LD_{50} is usually expressed as weight of test substance per kilogram of body weight (mg/kg or g/kg).

LC_{50} (Lethal $Concentration_{50}$) is the concentration of a substance in air or water (depending on the test population) that, when exposed to over a specified period of time, is expected to cause the death in 50% of a population. The LC_{50} is usually expressed as parts of test substance per million parts of air/water (ppm) for gases and vapours, or as milligrams per litre or cubic metre of air (mg/L or mg/m^3) for dusts, mists and fumes.

Note that the lower the LD_{50} or $LC_{50,}$ the more toxic the material.

7.2.2 Exposure Values (TWAEV, STEV, CEV)

An exposure limit is the maximum limit of exposure to an air contaminant. Exposure values can be expressed as the following:

- TWAEV (8-hour Time-Weighted Average Exposure Value): average concentration to which most workers can be exposed during an 8-hour workday, day after day, without adverse effects.
- STEV (Short-Term Exposure Value): maximum average concentration to which most workers can be exposed over a 15-minute period, day after day, without adverse effects.
- CEV (Ceiling Exposure Value): the concentration that must never be exceeded (applies to many chemicals with acute toxic effects).

7.2.3 Flash Point

The flash point is the lowest temperature at which a liquid produces enough vapour to ignite in the presence of an ignition source. The lower the flash point, the greater the risk of fire. Common laboratory solvents such as acetone, toluene, acetonitrile and methanol all have flash points that are below room temperature.

7.2.4 Flammable Limits

Flammable 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:

- LEL (lower explosive limit) or LFL (lower flammable limit): 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.
- UEL (upper explosive limit) or UFL (upper flammable limit): highest vapour concentration that will ignite. Above this limit, the mixture is too "rich" for ignition, i.e., the mixture has enough fuel but insufficient oxygen.
- The flammable range consists of concentrations between the LEL and UEL.
- Refer to Table 1 for a listing of flash points, lower explosive limits and exposure limits (8-hour time-weighted averages) of several flammable /combustible laboratory solvents.

Table 1: Flash points, lower explosive limits and exposure limits (8-hour time-weighted averages) of several flammable/combustible laboratory solvents.

Solvent	Flash Point * (°C)	LEL * (% by volume)	Autoignition temp** (°C)	TLV (TWA) * (ppm)
Acetic acid, glacial	39	4.0	427	10
Acetone	-18	2.5	465	250
Acetonitrile	5.6	3.0	524	20
Diethyl ether	-45	1.9	160	400
Ethanol, absolute	13	3.3	363	1000
Ethyl acetate	-4.4	2.0	426	400
Methanol	11	6.0	464	200
n-Pentane	-49	1.5	260	120
Toluene	4.4	1.1	422	100

TLV – Threshold Limit Value
*NIOSH Pocket Guide to Chemical Hazards, www.cdc.gov
** Corresponding MSDS

7.3 WHMIS TRAINING

Training is mandatory for all faculty, staff, students and/or volunteers who work with or in close proximity to hazardous materials. The training program is coordinated by SHERM. Information about WHMIS training and registration is available at (http://www.wlu.ca/sherm). Both online and in class sessions are available.

The WHMIS regulation requires individuals to demonstrate their competence; the intent is to ensure that trainees will use the information to protect their health and safety. To fulfill the competency requirement, employees and students are required to complete a WHMIS quiz at the end of the training session. A passing grade is 70% or higher.

7.4 WHMIS SYMBOLS

The classes of controlled chemical products and their corresponding symbols or pictograms, along with general characteristics and handling precautions, are outlined in Table 2.

Table 2: Summary of WHMIS classes, their associated characteristics, and proper handling and storage procedures.

	Class A - Compressed Gas	Contents under high pressure. Cylinder may explode or burst when heated, dropped or damaged.
	Class B - Flammable and Combustible Material	May catch fire when exposed to heat, spark or flame. May burst into flames.
	Class C - Oxidizing Material	May cause fire or explosion when in contact with wood, fuels or other combustible material.
	Class D, Division 1 - Poisonous and Infectious Material: Immediate and serious toxic effects	Poisonous substance. A single exposure may be fatal or cause serious or permanent damage to health.
	Class D, Division 2 - Poisonous and Infectious Material: Other toxic effects	Poisonous substance. May cause irritation. Repeated exposure may cause cancer, birth defects, or other permanent damage.
	Class D, Division 3 - Poisonous and Infectious Material: Biohazardous infectious materials	May cause disease or serious illness. Drastic exposures may result in death.
	Class E - Corrosive Material	Can cause burns to eyes, skin or respiratory system.
	Class F - Dangerously Reactive Material	May react violently causing explosion, fire or release of toxic gases, when exposed to light, heat, vibration or extreme temperatures

http://www.ccohs.ca/oshanswers/legisl/whmis_classifi.htmL, June 15, 2006

8. General Laboratory Safety

8.1 GENERAL SAFETY

- Know and understand the hazards, safe handling and operating procedures of the materials, equipment and methods being used. Review MSDSs, equipment manuals, and standard operating procedures as applicable.
- Familiarize yourself with the location of fire alarms, emergency exits, fire extinguishers and eyewash/safety shower stations.
- If you are unsure of any aspect of the work to be done (e.g., safe handling of material, operation of equipment, experimental technique, etc.), ask your supervisor before proceeding.
- Mouth pipetting is strictly prohibited.
- Footwear must cover feet completely; no open-toe shoes.
- Approved eye or face protection must be worn continually when working with chemicals.
- Restrain loose clothing, long hair and dangling jewellery.
- Running, horseplay, and practical jokes are prohibited.
- Report accidents and near misses promptly to your supervisor.
- Application of cosmetics or lip balm in the lab is prohibited.

8.2 HOUSEKEEPING

Good housekeeping practices are essential in every workplace. They are especially important in the laboratory environment, where spills from broken reagent containers, sample bottles, reaction vessels, etc. can create unnecessary exposure to potentially hazardous substances. Laboratory personnel are responsible for ensuring that their work spaces are kept as clean as the work allows. Laboratory supervisors are responsible for ensuring the overall cleanliness of the lab. The following housekeeping points will help lead to a neat, organized, efficient and most important a safe work environment:

- Stairways, hallways, and aisles must be kept clear and must not be used for storage. This includes equipment and personal property.
- Access to emergency equipment and exits must never be blocked.
- Equipment and chemicals must be properly stored and labelled.
- Spilled chemicals must be cleaned up immediately by the user if he/she feels safe doing so. Proper protective equipment must be worn when cleaning spills. Consult MSDS.
- Waste must be placed in appropriate and labelled containers.
- Old or unlabelled equipment/chemicals must not be allowed to accumulate. They must be identified, then disposed of immediately when no longer required.
- Ensure that cleanup is done once experiments are completed and that the work area is tidied at the end of each day.
- Electrical cords, hoses, and air lines must be secured.
- Do not store large, awkward, heavy or breakable items on high shelves.

- A step stool must be available to access items stored on high shelves.

8.3 FOOD STORAGE AND CONSUMPTION

- Storage and consumption of food and/or drink (including water) in research and teaching laboratories and chemical storage areas is **strictly prohibited.**
- The use of laboratory equipment including but not limited to glassware, refrigerators, freezers, microwave and other ovens, etc. to store or prepare food is strictly prohibited. Ice from laboratory ice-makers may not be consumed.

8.4 SMOKING

Smoking is strictly prohibited in all university buildings, and within 10 meters (30 ft) of any university building. This policy must be adhered to by all university employees and enforced by all university employees in a position of authority, including campus security. For more details on the university smoking policy, please visit: http://www.wlu.ca/documents/20129/Policy_7.8_Smoking.pdf.

8.5 WORKING ALONE

Laurier has a working alone policy that provides guidelines for prudent operational practices. These guidelines are not intended to be detrimental to the research process. They have been developed following due consideration of the university's ability to monitor activities and enforce compliance on a diverse campus. To read the Working Alone policy, please visit: *www.wlu.ca/sherm*.

8.6 UNATTENDED PROCEDURES

Non-routine, unattended laboratory procedures should be minimized. Only procedures that are deemed safe if left unattended may continue without personnel present in the laboratory. The laboratory supervisor must review procedures to ensure all hazards are controlled prior to leaving the experiment unattended.

The following are requirements for non-routine unattended laboratory procedures.

- Unattended procedures should be visited periodically. An Unattended Procedures Form must be posted in the area outlining the procedure and providing contact information for the person conducting the experiment. See Appendix A for a blank copy of the Unattended Procedures Form.
- Unattended heating may be done only with heating equipment that reliably maintains stable temperatures.
- Remove any flammable or combustible materials from the area, including hazardous waste.
- Sash doors must be closed on all fumehoods.

8.7 LABORATORY ENTRANCE RESTRICTIONS

In light of potential hazards in laboratory settings, and to protect the integrity of the research being performed and the security of equipment and supplies, the laboratory supervisor should escort all visitors to the lab. The supervisor may not knowingly permit entrance to the lab to anyone under the age of 14 or anyone not qualified to be in or about the workplace.

For special circumstances, for example the 'Take your kids to work program', written permission from a parent or guardian and departmental approval may be required to permit the entrance of a minor into a laboratory. Contact SHERM at ext 2874 for details.

9. Personal Protective Equipment

Personal protective equipment (PPE) must be used as required and consistent with the hazards present in each laboratory, as determined by the laboratory supervisor. While hygienic research procedures and engineering controls such as fumehoods are the primary means of protecting laboratory personnel, PPE is a necessary second level of protection. This section provides minimum standards for personal protective equipment.

9.1 PROTECTIVE CLOTHING

- It is recommended that the minimum skin protection in a laboratory in which hazardous chemical are used requires continuous coverage from shoulders to toes, including closed toed shoes.
- Laboratory coats must be worn at all times. The coat must cover the arms and the middle body, and be buttoned properly.
- Avoid wearing laboratory coats outside the work area.
- Laboratory coats must never be washed with domestic laundry.
- Long pants are recommended to protect legs against chemical splashes.

9.2 EYE AND FACE PROTECTION

Canadian Standards Association (CSA) approved eye protection must be worn by students, staff, and visitors in all areas where hazardous or unknown substances (either chemical or biological) are stored, used or handled, when there is a risk of splash. Eye protection must provide adequate resistance to impact and splash for the work being done.

- Minimum eye protection for the laboratory consists of approved safety glasses with permanent side shields. Note that safety glasses do not provide significant splash resistance and therefore should only be worn for light work that does not involve the use of liquids.
- Goggles must be worn when there is a risk of splash of a hazardous material.

- Contact lenses are not protective devices and must not be worn when working with chemicals.

9.3 FOOT PROTECTION

Closed-toed, closed-heeled shoes constructed of a resistant material (preferably leather) are required for work in all laboratories. Chemical- resistant safety shoes may be warranted in specific cases as determined by the laboratory supervisor. Sandals do not provide adequate protection and must not to be worn in any laboratory setting. High-heeled shoes are strongly discouraged as they increase the potential for trips and falls in the lab.

9.4 HEARING PROTECTION

Equipment such as grinders or homogenizers in laboratories may warrant the use of hearing protection. Hearing protection may consist of ear plugs or ear muffs depending on the amplitude and frequency of the noise.

Hearing protection is required in areas where the eight hour time weighted average noise level is greater than 85 dB.

SHERM can take noise level measurements to determine the average noise level. Laboratory supervisors should contact SHERM at extension 2817 to arrange for this testing.

9.5 RESPIRATORY PROTECTION

Under normal circumstances, respirators should not be required for laboratory situations at Laurier. Appropriate use of fume hoods should generally eliminate respiratory hazards. However, there are situations that the use of respirator may be necessary. For example, when working with lab animals where allergens are a problem.

The use of a respirator should also be considered when permanent engineering controls are inadequate (e.g., emergency spill situations) or not functioning as a result of an emergency situation. For questions regarding the use of respirators, contact SHERM at 2817.

Prior to using a respirator, the user must receive training and be fit tested to ensure adequate protection. SHERM can arrange for the fit testing.

9.6 HAND PROTECTION

9.6.1 Selection of Gloves

Gloves must be used to provide protection against chemical or biological agents, exposure to extreme temperatures, and abrasions or lacerations. Table 3 provides general guidelines for appropriate hazard-based selection of gloves.

Table 3: Guide to Hazard Based Glove Selection

HAZARD	DEGREE OF HAZARD	PROTECTIVE MATERIAL
Abrasion	Severe	Reinforced heavy rubber, staple-reinforced heavy leather
	Less Severe	Rubber, plastic, leather, polyester, nylon, cotton
Sharp Edges	Severe	Metal mesh, staple-reinforced heavy leather, Kevlar™, aramid-steel mesh
	Less Severe	Leather, terry cloth (aramid fiber)
	Mild with delicate work	Lightweight leather, polyester, nylon, cotton
Chemicals and fluids	Risk varies according to the chemical, its concentration, and time of contact among other factors. Refer to the manufacturer, or product MSDS.	**Dependant on chemical**. Examples include: Natural rubber, neoprene, nitrile rubber, butyl rubber, PTFE (polytetrafluoroethylene), Teflon™, Viton™, polyvinyl chloride, polyvinyl alcohol, Saranex™, 4H™, Barricade™, Chemrel™, Responder™, Trellchem™
Cold		Leather, insulated plastic or rubber, wool, cotton
Electricity		Rubber-insulated gloves tested to appropriate voltage (CSA Standard Z259.4-M1979) with leather outer glove
Heat	Greater than 350°C	Zetex™
	Up to 350°C	Nomex™, Kevlar™, heat-resistant leather with linings
	Up to 200°C	Nomex™, Kevlar™, heat-resistant leather, terry cloth (aramid fiber)
	Up to 100°C	Chrome-tanned leather, terry cloth
General Duty		Cotton, terry cloth, leather
Product Contamination		Thin-film plastic, lightweight leather, cotton, polyester, nylon
Radiation		Lead-lined rubber, plastic or leather, refer to the Radiation Safety Manual for more details

9.6.2 Chemical Resistance

No one type of glove material is appropriate for protection against all potential chemical exposures as the permeation rate (rate at which the chemical seeps through the glove material) of glove types varies significantly with different chemicals. Consult the MSDS and consider the work being performed to determine an appropriate glove. Table 4 (page 18) provides some basic information about selecting gloves suitable for chemical applications.

The following links provide more detailed information on proper glove material selection.

- Ansell Chemical Resistance Guide: http://www.ansellpro.com/download/Ansell_7thEditionChemicalResistanceGuide.pdf

- Best Manufacturing Company's Chemrest: www.showabestglove.com

Table 4: Characteristics, Advantages, Disadvantages and Uses of Selected Chemical Resistant Glove Materials.

TYPE	ADVANTAGES	DISADVANTAGES	FOR USE WITH:
Natural rubber latex	Low cost, good physical properties, dexterity	Poor against oils, greases, organic solvents, ethidium bromide. May cause allergic reactions.	Bases, acids, alcohols, dilute aqueous solutions. Fair vs. aldehydes, ketones.
Natural rubber blends	Low cost, dexterity, generally better chemical resistance than natural rubber.	Physical properties often inferior to natural rubber. May cause allergic reaction.	Bases, acids, alcohols, dilute aqueous solutions. Fair vs. aldehydes, ketones.
Polyvinyl chloride (PVC)	Low cost, very good physical properties, average chemical resistance.	Plasticizers can be stripped.	Strong acids and bases, salts, aqueous solutions, alcohols, oils, greases and petroleum products.
Neoprene	Average cost, average chemical resistance, average physical properties, high tensile strength, high heat resistance.	Poor vs. chlorinated hydrocarbons	Oxidizing acids, alcohols, anilines, phenol, glycol ethers, solvents, oils, mild corrosives
Nitrile	Low cost, excellent physical properties, dexterity	Poor vs. chlorinated organic solvents	Oils, greases, aliphatic hydrocarbons, xylene, perchloroethylene, trichloroethane, ethidium bromide. Fair vs. toluene.
Butyl	Good resistance to polar organics, high resistance to gas and water vapour	Expensive, poor vs. hydrocarbons, chlorinated solvents	Glycol ethers, ketones, esters, aldehydes, polar organic solvents
Polyvinyl alcohol (PVA)	Resists broad range of organics, good physical properties.	Very expensive. Water sensitive, poor vs. light alcohols, acids and bases.	Aliphatic and aromatic hydrocarbons, chlorinated solvents, ketones (except acetone), esters, ethers
Fluro-elastomer (Vitron®)	Good resistance to organic and aromatic solvents. Flexible.	Extremely expensive. Poor physical properties. Poor vs. some ketones, esters, amines	Aromatics and aliphatic hydrocarbons, chlorinated solvents, oils, lubricants, mineral acids, alcohols.
Norfoil, Silver Shield™, 4H™	Excellent chemical resistance.	Poor fit, stiff, easily punctures, poor grip.	Use for Hazmat work. Good for range of solvents, acids and bases.

9.6.3 Use and Care of Gloves

The following guidelines should be considered when using gloves:

- Gloves should be inspected for damage prior to use. Replace gloves showing any sign of deterioration such as holes, tears, or discoloration.
- Gloves should be of adequate length to provide protection of the arm.
- Remove gloves by pulling inside out to prevent exposure during removal.
- Remove gloves before touching computers or phones, opening doors or contacting items that one would expect to be free of contamination (either biological or chemical).
- Wash hands thoroughly after removing gloves.
- Never reuse disposable gloves.

10. Emergency Procedures and Equipment

10.1 ACCIDENT/INCIDENT REPORTING

All accidents, incidents and near misses must be reported to SHERM via the Accident Report Form that is found under "Forms" on the SHERM website (www.wlu.ca/sherm). To meet regulatory requirements, these forms must be submitted to SHERM within 24 hours of occurrence, with the exception of critical injuries, which must be reported immediately to the SHERM by telephone, extension 2875.

Critical injuries meet at least one of the following criteria:

a. place life in jeopardy,
b. produce unconsciousness,
c. result in substantial loss of blood,
d. involve fracture of a leg or arm but not a finger or toe,
e. involve amputation of a leg, arm, hand or foot, but not a finger or toe,
f. consist of burns to a major portion of the body, or
g. causes the loss of sight in an eye.

(R.R.O. 1990, Reg. 834)

Additional details regarding incident reporting can be found on the SHERM website (www.wlu.ca/sherm) under "Accident Reporting and WSIB".

10.2 ACCIDENT/INCIDENT INVESTIGATION

Accident/incident investigation is an important component in the continuous improvement of the university's health and safety practices and procedures. The active participation of both supervisors and workers in this program is essential.

The purpose of an investigation is to identify and address all causes of an accident or incident, and to uncover the underlying factors and root causes, which may not be immediately evident on initial review of the accident/incident. It is essential that the scene of an accident/incident be preserved so a thorough and accurate investigation can be performed. Scenes of critical injuries must be preserved by law until permission is given by the Ministry of Labour Inspector.

To investigate an accident/incident thoroughly, consider the following strategies:

a. Gather data
b. Answer the following questions:
    - What happened
    - Why
    - When and where
c. Determine root causes and contributing factors:
    - People
    - Equipment
    - Material
    - Environment
    - Process

SHERM and the University's Joint Health & Safety committee members are available to assist in investigations and will perform their own investigations as necessary.

10.3 LABORATORY ORIENTATION

As part of orientation, it is the supervisor's responsibility to ensure that all lab personnel are familiar with the use and location of the following equipment and safety aids *in all areas* in which they will be working.

- Fire extinguisher
- Eye wash station
- Safety shower
- Fire alarm pull station
- Emergency routes and exits
- Electrical equipment
- First aid kits
- Spill kits
- MSDSs

All personnel working in a laboratory are strongly encouraged to become familiar with the building's evacuation plan, and to identify their Building Coordinators and Emergency Wardens. Individual plans can be found on the SHERM website www.wlu.ca/sherm under "Emergency Procedures and Fire Safety".

10.4 LABORATORY EMERGENCY PROCEDURES

It is the laboratory supervisor's responsibility to communicate to all lab personnel the emergency procedures associated with the particular materials, equipment, samples,

procedures, personnel, and other factors associated with the lab. Laboratory supervisors are responsible for ensuring that there are appropriate evacuation procedures in place for those persons with mobile difficulties.

All lab personnel, including students, must participate in emergency drills as applicable and respond to all fire alarms by following emergency procedures and promptly evacuating the building. Elevators may not be used during an evacuation. Buildings that have been evacuated may be re-entered only after permission has been given by the Building Coordinator, Special Constable Service, or the City of Waterloo Fire Rescue.

For detailed fire safety plans specific to each building please refer to the SHERM website at http://www.wlu.ca/sherm under "Emergency Procedures and Fire Safety".

10.5 LABORATORY FIRES

- Vacate the area and close the doors
- Activate the nearest emergency pull station and call 9-911 and/or Special Constable Service.
- Attempt to extinguish the fire only if you are trained to do so and if you can extinguish the fire without putting your own safety or the safety of others at risk:
    - Never try to extinguish a fire larger than a waste paper basket
    - Locate a fire extinguisher appropriate for the type of fire.
    - Position yourself between the fire and the exit, so that you always have a route out of the area.
    - Pull the pin.
    - Aim the extinguisher nozzle or hose at the base of the flame.
    - Squeeze the trigger.
    - Sweep. Using a sweeping motion, extinguish the fire.
- Most portable extinguishers contain only enough material for 8 - 25 seconds of action, depending on their size.
- If at any time the fire becomes uncontrollable, activate the fire alarm and leave the building by the nearest safe emergency exit.
- Report to the Building Evacuation Coordinator or other emergency responders to ensure that all relevant information is available to them.

If your clothing catches on fire:

- Stop
- Drop to the floor
- Roll to smother the flames
- Get to the safety shower, if possible, and rinse with copious amounts of water
- Seek medical attention

10.6 EMERGENCY EQUIPMENT

10.6.1 Fire Extinguishers

There are five classes of fires. The fifth class is not applicable to laboratories, as it represents cooking oil fires. The four applicable classes are listed below:

Ordinary Combustibles e.g. paper, wood, rubber, many plastics

Flammable Liquids e.g. flammable and combustible liquids, oils, greases, tars, oil based paints, flammable gases, lacquer.

Energized Electrical Equipment e.g. wiring, fuse boxes, circuit breakers, plugged-in electrical equipment

Combustible Metals e.g. sodium, lithium, aluminum, titanium

The type of fire extinguisher used to control a fire depends on the type of fire itself. Extinguishers are rated A, B, C, D and F or combinations thereof. Each laboratory has an ABC (dry chemical) and may also have a BC (CO_2) rated extinguisher. Any laboratory using combustible metals must has a D-rated extinguisher.

Fire extinguishers should be conspicuously located. Additional signage should prominently indicate the location of the extinguisher. Fire extinguishers should be located near the exit(s) of the laboratories and must be unobstructed and easily accessible at all times.

Any use of a fire extinguisher must be reported immediately so the extinguisher can be recharged or replaced. Contact your local Physical Resources department; see the contact list at the beginning of this manual.

10.6.2 Emergency Showers and Eyewash Stations

Emergency (safety) showers and eyewash stations provide on-the-spot decontamination after exposure to a chemical. Treatment in the first 15 to 20 seconds following an exposure is critical to prevent serious injury, particularly when working with a corrosive substance.

- Design and construction of all new installations of eyewash stations and emergency showers should meet the requirements in American National Standards Institute (ANSI) standard Z358.1.
- Eyewash stations and emergency showers for each laboratory must be readily available and easily accessible, i.e., less than 30 metres from a hazard, and with direct-path accessibility within 10 seconds or less.
- Eyewash stations and emergency showers must be unobstructed at all times.
- Emergency showers and eyewash stations should have prominent additional signage to indicate their location.
- Eyewash stations must be activated at least weekly by personnel in the work area to verify that they are operating properly and to flush pipes.
- Any malfunction of an emergency shower or eyewash station must be reported immediately. Contact your local Physical Resources department; see the contact list at the beginning of this manual.

Guidelines are based on ANSI Standard Z358.1.

10.6.3 Chemical Contact

For skin contact:

- For a small, easily accessible area of the skin (e.g., hand)
    - Proceed to the nearest sink.
    - Remove contaminated clothing and jewellery.
    - Rinse for at least 15 minutes.
- For a large or inaccessible area of skin
    - Remove contaminated clothing and jewellery
    - Go to the nearest emergency shower.
    - Rinse for at least 15 minutes.
- Seek medical attention if required. Provide applicable MSDS to medical personnel.

For contact with the eyes:

- Go to the nearest eyewash station.
- Rinse for at least 15 minutes.
- If 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.
- Seek medical attention. Provide applicable MSDS to medical personnel.

11. Specific Chemical Hazards

All chemicals used in the laboratories at Laurier should be handled with caution, in keeping with good laboratory practices. Certain chemicals or classes of chemicals require specific handling precautions, described briefly in the following sections. It is beyond the scope of this manual to address the hazards associated with all of the chemicals that may be found in the university's laboratories and the precautions required in working with them. For more information about the toxicity, safe handling and use of specific chemicals, the appropriate MSDS and if necessary references such as those listed below should be consulted:

- NIOSH Pocket Guide to Chemical Hazards, (http://www.cdc.gov/niosh/npg/npg.htmL)
- Sax's Dangerous Properties of Industrial Materials, Richard Lewis. Published by John Wiley and Sons Inc.

11.1 FLAMMABLES

Flammable materials present a serious hazard to laboratory personnel. Steps must be taken to ensure their appropriate use, handling and storage.

- Ensure containers are grounded appropriately when transferring liquid from one container to another.
- Ensure that potential ignition sources are identified and removed from the area surrounding the flammable material.

11.2 OXIDIZERS

Oxidizers are capable of igniting flammable and combustible material even in oxygen-deficient atmospheres. They can increase the intensity of a fire by adding to the oxygen supply and causing ignition and rapid burning of normally non-flammable materials. Oxidizers can also:

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

11.2.1 Solids

Solid oxidizing agents have the ability to form explosive mixtures with common materials such as sugar, charcoal, starch, sawdust and sulfuric acid. Examples of solid oxidizers include metallic:

- Chlorates;
- Perchlorates (these are especially dangerous and their use should be avoided);
- Nitrates;
- Chromates; and
- Permanganates.

11.2.2 Liquids

Liquid oxidizers are often strong acids as well, making them powerful corrosives. Examples include:

- **Perchloric acid**. Use of perchloric acid should be avoided if possible. If use is necessary, procedures must be performed by personnel trained in specific handling. All work must be performed in specialized, dedicated chemical fumehoods. Note that anhydrous perchloric acid and perchlorate crystals which may form around the cap of the container are shock-sensitive explosives.
- **Nitric acid**
- **Chromic acid**
- **Sulfuric acid**

Personal protective equipment when working with these compounds should include a face shield, goggles, synthetic rubber apron, lab coat and synthetic rubber gloves.

11.3 TESTING FOR PEROXIDES

There are certain common compounds that can form dangerous levels of potentially explosive peroxides upon storage and contact with air (see Table 5).

In order to allow a simple and quick determination of whether peroxides are present in a solution, commercially available peroxide test strips can be purchased from laboratory supply companies.

Table 5: Examples of Peroxidizable Compounds.

Peroxide Hazard in Storage: ***Discard After Three Months***	
Divinyl acetylene	Potassium metal
Divinyl ether	Sodium amide
Isopropyl ether	Vinylidene chloride
Peroxide Hazard in Concentration: ***Discard After One Year***	
Acetal	Dioxane
Cumene	Ethylene glycol dimethyl ether (glyme)
Cyclohexene	Furan
Cyclopentene	Methyl acetylene
Diacetylene	Methylcyclopentane

Dicyclopentadiene Diethyl ether Diethylene glycol dimethyl ether (diglyme)	Methyl isobutyl ketone Tetrahydronaphthalene (Tetralin) Tetrahydrofuran Vinyl ethers
Hazard Due to Peroxide Initiation of Polymerization: ***Discard After One Year***	
Acrylic acid Acrylonitrile Butadiene Chloroprene Chlorotrifluoroethylene Methyl methacrylate	Styrene Tetrafluoroethylene Vinyl acetylene Vinyl acetate Vinyl chloride Vinyl pyridine

Table reproduced July 11, 2006 from: http://web.princeton.edu/sites/ehs/labsafetymanual/.

As an alternative to the commercially available strips, the following colorimetric test can be performed.

1. Prepare a 5 % (w/v) potassium iodide or sodium iodide aqueous solution (5 g of KI or NaI per 100 mL of water).
2. Add a couple of drops of iodide solution prepared above to ~ 2 mL of glacial acetic acid.
3. Add ~ 2 mL of the solution in question to the ~ 2 mL of glacial acetic acid/iodide solution.
4. Yellow indicates a low concentration of peroxide (<0.01 %). Brown indicates a high/hazardous concentration of peroxide (> 0.01%).

Note that this test method above should not be applied to solutions that may contain inorganic peroxides.

11.4 CORROSIVES

Corrosive chemicals are commonly found in laboratories as solids, liquids and gases. These materials have the ability to damage tissue at the site of contact.

11.4.1 Corrosive Liquids

Corrosive liquids can be particularly hazardous as they act rapidly upon contact. Examples of common corrosive liquids are:

- Strong acids (chromic acid, hydrochloric acid, nitric acid, etc. Hydrofluoric acid may be fatal through inhalation, absorption or ingestion and causes extensive, deep and painful burns. Avoid use if possible.)
- Strong bases (aqueous sodium hydroxide, potassium hydroxide, ammonia, etc.)
- Strong oxidizing agents (peroxides, etc.)

11.4.2 Corrosive Solids

Inhalation of corrosive dusts presents a particular hazard as the point of contact and the injured tissue, which may belong to the lungs, is internal, creating significant damage that may be difficult to treat and heal. Examples of corrosive solids are lithium oxide, sodium sulphide and phenol, phosphorus pentoxide, calcium oxide, etc.

11.4.3 Use and Handling of Corrosives

Specific precautions to take when using or handling corrosive materials include the following:

- Ensure that acids are always added to water and not vice versa.
- Be prepared for heat generation when diluting or dissolving in water.
- Ensure all work is completed in a chemical fumehood with adequate ventilation.
- Must wear appropriate personal protective equipment.

11.5 HIGHLY REACTIVE MATERIALS

Reactive materials are used for various purposes in the lab, often because of their reactive properties. Particular care must be taken to ensure safe handling, use and storage of these sensitive chemicals.

11.5.1 Water Reactives

The following situations may occur with water reactive chemicals on contact with water:

- Liberation of heat (causing potential ignition of the chemical itself or nearby flammable material);
- Release of flammable, toxic, or oxidizing gas;
- Release of metal oxide fumes (applicable to water reactive metals);
- Formation of corrosive acids.

Examples of water reactive materials:

Alkali metals including lithium, sodium and potassium	Alkylaluminums including triethylaluminum and Alkyllithiums
Silanes	Magnesium
Aluminum chloride	Phosphorus
Phosphorus pentachloride	Phosphorus pentasulphide
Ferrous sulphide	Maleic anhydride
Sodium borohydride	Acetyl chloride
Chlorosulphonic acid	Phosphoryl trichloride
Sulphur chloride	Sulphuryl chloride
Thionyl chloride	Titanium tetrachloride

Care must be taken to ensure that water reactive chemicals are handled and stored away from sinks, water baths or other sources of moisture.

11.5.2 Pyrophorics

Pyrophoric chemicals ignite spontaneously on contact with air. Pyrophorics must be handled and stored in such a way as to prevent exposure to air (e.g. storage under an inert gas or under kerosene).

Examples of pyrophorics:

Boron	Chromium*
Calcium*	Diborane
Cobalt*	Diethylzinc
Dichloroborane	2-Furaldehyde
Iron*	Lead*
Manganese*	Nickel*
Phosphorus*	Phosphine
Cadmium*	Titanium*
Alkyllithiums	

*Finely divided metals form a pyrophoric hazard.

11.5.3 Explosives

Explosives are regulated by the Canadian Explosives Act and corresponding regulations.

11.5.3.1 Picric Acid

Picric acid (2,4,6-trinitrophenol) is a reagent used as a component in some biological specimen preserving solutions. When dehydrated, picric acid itself is a dangerous explosive. When in contact with metal, highly shock-sensitive picrate salts can be formed. The following guidelines for the storage and handling of picric acid:

- Picric acid must be stored in water.
- Containers of picric acid are to be inspected at least every 6 months and distilled water added to the containers as necessary to ensure that the picric acid never dries out.
- Ensure the lid of the container of picric acid is securely fastened.
- Containers and lids for storage of picric acid or solutions of picric acid must not be of metal construction.
- Metal spatulas are never to be used to remove material from its container.
- Always wipe the neck of the bottle, and the cap with a wet cloth before returning to storage.

Disposal costs associated with dry picric acid are substantial and are the responsibility of the applicable lab supervisor or department.

11.6 CRYOGENIC MATERIALS

Cryogenics are very low temperature materials such as dry ice (CO_2(s)), liquefied air, nitrogen, helium, oxygen, argon and neon. The following hazards are associated with the use of cryogenics:

- Asphyxiation due to displacement of oxygen (for materials other than liquefied air and oxygen);
- Freezing and brittling of materials from extreme cold;
- Frostbite;
- Explosion due to pressure build-up; and
- Condensation of oxygen and fuel such as hydrogen or hydrocarbons resulting in explosive mixtures.

The following are precautions for handling cryogenics:

- Always handle these liquids carefully to avoid skin burns and frostbite. Exposure that may be too brief to affect the skin of the face or hands may damage delicate tissues, such as the eyes.
- Protect skin and eyes from contact; wear eye protection and insulated gloves.
- Wear safety goggles when breaking large pieces of dry ice or using mixtures of dry ice and solvent.
- Wear a face shield when removing samples from storage dewars due to the possibility of rupture from pressure build-up.
- Use and store in well-ventilated areas. Alarmed oxygen sensors may be required in areas where the volume of gas could result in the displacement of oxygen, thereby causing an asphyxiation hazard.
- Keep away from sparks or flames.
- Use materials resistant to embrittlement (e.g. rubber tubing).
- Watches, rings, bracelets or other jewelry that could trap fluids against flesh should not be worn when handling cryogenic liquids.

- Never store dry ice in a refrigerator/freezer (especially deep chest freezers). Dry ice will sublimate at -78°C and could asphyxiate the person opening the equipment.
- Boiling and splashing always occur when charging or filling a warm container with cryogenic liquid or when inserting objects into these liquids. Perform these tasks slowly to minimize boiling and splashing. Use tongs to withdraw objects immersed in a cryogenic liquid.
- Cylinders and dewars should not be filled to more than 80% of capacity, since expansion of gases during warming may cause excessive pressure build-up.

11.7 DESIGNATED SUBSTANCES

There are eleven "designated substances" regulated by the Ontario Occupational Health and Safety Act because of their potential serious health implications. Use of designated substances in research or teaching should be avoided. However, because suitable substitution may not be possible, some of these substances are found in university laboratories. Designated substances are listed below:

- acrylonitrile
- arsenic
- asbestos
- benzene
- coke oven emissions
- ethylene oxide
- isocyanates
- lead
- mercury
- silica
- vinyl chloride

Designated substance regulations apply to all workers at workplaces where the substance is present and is likely to be inhaled, ingested or absorbed by the worker. The regulations require that the time weighted average exposure of the worker to the substance is less than limits prescribed in the regulations themselves. Generally designated substance regulations contain three key components:

- Assessment – the employer is required to consider the worker exposure or likelihood of exposure to the substance.
- Control program – a formal document program, required if the assessment discloses that a worker is likely to be exposed to the substance. The program must include engineering controls, hygiene practices, work practices and Physical Resources to ensure that the worker exposure to the substance is controlled.
- Monitoring – air emissions monitoring and medical surveillance are required to determine actual exposure to the substance.

It is the responsibility of the laboratory supervisor to ensure that such a program exists in their area. A designated substance assessment form for each designated substance in use or in storage must be completed and submitted to SHERM for review. The form can be found on the SHERM website, under Laboratory Safety.

11.8 HAZARDS OF COMPRESSED GASES

Compressed gases are inherently hazardous due to the high pressure inside the cylinders. Knocking over an unsecured, uncapped cylinder of compressed gas can break the cylinder valve and result in a rapid escape of high-pressure gas that can transform a cylinder into an uncontrollable rocket or pinwheel, causing serious injury and damage. 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 or restricted areas and causing asphyxiation.
Information about compressed gases training and registration is available at http:/www.wlu.ca/sherm .

11.8.1 Handling and Transport of Gas Cylinders

The following guidelines should be used for safe handling and transport of gas cylinders.

- Return unlabelled cylinders unopened to the supplier. Colour coding does not provide sufficient identification.
- When cylinders are being transported, regulators must be removed and the protective cap must be attached.
- An appropriate cylinder cart must be used for transporting cylinders. Cylinders must be chained or strapped to the cart.
- Ensure that propane tanks designed for outdoor use are not stored or used indoors.
- Label empty cylinders clearly with either “EMPTY” or “MT” and move to the designated storage area for empty cylinders for pickup by the supplier.
- Never bleed a cylinder completely empty; leave a residual pressure of at least 25 psi to prevent contamination or “suck back”.
- Do not lubricate regulators. The mixture of lubricant and oxidizing gases could be explosive.
- Do not force, lubricate or modify cylinder valves in any way.
- Cylinders containing flammable gases must be grounded to prevent accumulation of electrostatic charge.
- Never expose skin or clothing to compressed gas flow as high velocity gas could penetrate the skin and cause serious injury.
- To use a cylinder:
    - Ensure the pressure regulating valve (adjusting screw) is closed.
    - Open the cylinder valve slowly.
    - Open the pressure regulating valve to the desired pressure.
- To shut off the gas:
    - Close the cylinder valve.
    - Open the pressure regulating valve to relieve the pressure.

11.8.2 Valves and Regulators

- Verify that the regulator is appropriate for the gas being used and the pressure being delivered. Regulators are not universal and have to be chosen based on the gas and the cylinder in use. Compressed Gas

Association (CGA) connector numbers must be the same on the regulator and cylinder valve.
- Cylinder valve connections on regulators are designed to minimize the chances of using the wrong regulator by having threads that will fit only with the type of gas the regulator is designed for.
- Label all regulators appropriately and do not use regulators interchangeably with different gases.
- Do not rely on the pressure gauge to indicate maximum pressure ratings; check the regulator's specifications.
- Do not use adaptors or Teflon tape to attach regulators to gas cylinders. Regulator inlet connections are designed to fit the outlet connection of the cylinder valve of a particular gas. Gas tight connections are made using metal-to-metal seals and can be weakened or the lines plugged through the use of Teflon tape.
- When tightening the regulator nut and hose connections, always use a cylinder wrench or other tightly fitting wrench. **Do not use an oversized wrench, adjustable wrench, pliers or pipe wrench.** These tools may damage the fittings and make it impossible to tighten them properly.

11.8.3 Leaks

Most leaks occur at the valve in the top of the cylinder and may involve the valve threads, valve stem, valve outlet, or pressure relief devices. Lab personnel should not attempt to repair leaking cylinders. It is important to note that cryogenic liquid cylinders will vent periodically as part of their normal operation to relieve pressure. When a vent valve becomes frozen open, treat the cylinder as if it is leaking.

Where action can be taken without serious exposure to lab personnel:

- Move the cylinder to an isolated, well-ventilated area (away from combustible materials if the cylinder contains a flammable or oxidizing gas). Call Special Constable Service.
- Whenever a large or uncontrollable leak occurs, evacuate the area immediately and call 9-911from any campus phone and Special Constable Service.

11.8.4 Storage of Gas Cylinders

Storage of gas cylinders is regulated through the Ontario Fire Code Section 5.6. Only cylinders in use may be located in research or teaching labs.

- All cylinders must be secured to a wall, bench or fixed support using a chain or strap placed ½ to 2/3 high on the cylinder body. Cylinder stands may be used as an alternative to straps.
- Cylinders should be strapped individually.
- Do not store full and empty cylinders together.
- Oxidizers and flammable gases should be stored in areas separated by at least 20 feet or by a non-combustible wall.
- Cylinders should not be stored near radiators or other heat sources.

- No part of a cylinder should be subjected to a temperature higher than 52°C. A flame should never be permitted to come in contact with any part of a compressed gas cylinder.
- Do not place cylinders where they may become part of an electric circuit.
- Ensure that each cylinder is properly and prominently labelled as to its contents.

11.8.5 Segregation of Gas Cylinders

As with other chemical storage, certain compressed gases are incompatible with each other. Table 6 describes the segregation required for compressed gases.

Table 6: Compressed Gas Segregation

COMPRESSED GAS CYLINDER SEGREGATION AND STORAGE PLAN

X = may not to be stored together
√ = ok to be stored together

	Flammable compressed gases	Oxidizing compressed gases	Non-flammable Toxic compressed gases	Non-flammable, Non-Toxic compressed gases
Flammable compressed gases	√	X	X	√
Oxidizing compressed gases	X	√	√	√
Non-flammable Toxic compressed gases	X	√	√	√
Non-flammable, Non-Toxic compressed gases	√	√	√	√

Examples:	
Flammable compressed gases	methane, propane, acetylene, hydrogen
Oxidizing compressed gases	oxygen, bromine, chlorine
Non-flammable Toxic compressed gases	carbon monoxide, hydrogen sulphide
Non-flammable, Non-Toxic compressed gases	helium, nitrogen, air, carbon dioxide, argon

11.9 OTHER TOXIC MATERIALS

Some other chemical materials warrant mentioning due to their hazards and/or extensive usage. The primary hazards are identified below:

- Ethidium bromide – known mutagen.
- Chloroform – acutely toxic and carcinogenic.
- Hydrogen sulphide – acutely toxic. Attacks the respiratory system. Highly flammable.
- Formalin/Formaldehyde – carcinogen.

12. Chemical Handling and Storage

Because of limited space and waste disposal costs, and in keeping with good housekeeping practices and the desire to minimize hazardous materials within the laboratories, it is essential to procure reagents, solvents, etc. as needed, rather than buying in bulk.

12.1 GENERAL TRANSPORT PRACTICES

- Use a cart when transporting several containers or containers that are large, awkward or heavy. Carts should have high edges for containment, or chemicals should be in secondary containers.
- Transport off-site requires compliance with federal Transportation of Dangerous Goods regulations. Contact SHERM for details.

12.2 GENERAL STORAGE PRACTICES

- Store large containers on lower shelves.
- Avoid storing containers above eye level.
- Window sills, heaters and ledges may not be used as storage areas.
- Avoid storage on the floor unless the chemical container is in its original shipping carton and packing, or the container is an approved safety can.
- Inspect chemicals in storage regularly to ensure that:
    - There are no leaks.
    - Caps and containers are in good condition. Look for signs of discolouration, bulging and pressure build-up.
    - Containers' exteriors are free of spills and stains.

12.3 STORAGE OF FLAMMABLES AND COMBUSTIBLES

Definitions:
flammable liquid – a liquid having a flash point below 37.8°C and a vapour pressure not more than 275.8 kPa (absolute) at 37.8°C.
combustible liquid – any liquid having a flash point between 37.8°C and 93.3°C

Storage of flammable and combustible liquids in the laboratory is regulated by the Ontario Fire Code. Maximum quantities listed below are for single fire compartments with a minimum fire resistance rating of one hour.

- Ensure that the flammable and combustible material in the open lab area is minimized and is for **immediate use only** (less than a total of 300 L, of which no more than **50 L** is flammable liquid: Ontario Fire Code)
- Ensure that all additional flammable material (up to a total of 500 L of which not more than **235 L** is flammable liquid) is stored in approved flammable storage cabinets.
- Ensure that flammable materials requiring refrigeration are stored in refrigerators/freezers designed and certified for this purpose. **Household refrigerators must not be used to store flammable liquids.**
- Storage containers are to be less than 5 L unless they are safety containers conforming to ULC/ORD-C30. Safety containers must be less than 25 L capacity.

12.3.1 Approved Flammable Storage Cabinets

To be approved for storage of flammables, cabinets must conform to at least one of the following standards:

- ULC-C1275, "Storage Cabinets for Flammable Liquid Containers";
- ULI 1275, "Flammable Liquid Storage Cabinets";
- Factory Mutual Research Approved; **or**
- Meet NFPA 30.

Flammable storage cabinets either need to be vented actively to the outdoors or capped with the plugs supplied with the cabinet itself. While it is recommended that flammable storage cabinets are not vented, venting is acceptable provided that the venting design does not interfere with the integrity of the cabinet.

12.3.2 Chemical Segregation

It is critical that chemicals be stored to ensure that incompatible chemicals are not in close proximity. The recommended chemical segregation system is described in Table 7 on the following pages. It is suggested that solvents/reagents etc. be labelled according to the storage system to facilitate proper storage.

Table 7: Chemical Segregation System

CHEMICAL SEGREGATION AND STORAGE SYSTEM

	Water reactive/ Pyrophoric/Self -reactive	Explosives	Flammables (solids & liquids)	Oxidizers (solids & liquids)	Corrosive Acids (solids & liquids)	Corrosive Bases (solids & liquids)	Non-flammable solvents & regulated chemicals	Low-hazard solids & liquids
Water reactive/ Pyrophoric/Self-reactive	√	X	X	X	X	X	X	X
Explosives	X	√	X	X	X	X	X	X
Flammables (solids & liquids)	X	X	√	X	X	√	√	X
Oxidizers (solids & liquids)	X	X	X	√	X	X	X	Secondary containment required
Corrosive Acids (solids & liquids)	X	X	X	X	√	X	X	< 2 M acidic solutions
Corrosive Bases (solids & liquids)	X	X	√	X	X	√	Secondary containment required	< 2 M caustic solutions
Non-flammable solvents & regulated chemicals	X	X	√	X	X	Secondary containment required	√	√
Low-hazard solids & liquids	X	X	X	Secondary containment required	< 2 M acidic solutions	< 2 M caustic solutions	√	√

	√ – ok to be stored together	X – may not be stored together				

STORAGE INSTRUCTIONS:

Water reactive/ Pyrophoric/Self-reactive	Store in secondary container in secure, cool, dry location. Isolate from other groups. Separate from aqueous solutions. Protect from water (sprinkler systems etc.) If refrigeration is required double contain in bins.	Examples: lithium aluminum hydride, butyl lithium, sodium azide, sodium metal
Explosives	Store in secondary container in secure, dry location. Isolate from other groups.	Examples: ammonium nitrate, picric acid, nitro urea, trinitroaniline, trinitrobenzene, trinitrobenzoic acid, trinitrotoluene
Flammables (solids & liquids)	Store in approved flammable storage cabinet or approved flammable storage fridge/freezer Store solids above liquids. Includes combustibles.	Examples: methanol, acetonitrile, hexane, toluene, tetrahydrofuran, acetone
Oxidizers (solids & liquids)	Store in secondary container on lab shelf or in dedicated oxidizer cabinet Ensure isolation from reducing agents. Ensure compatibility between oxidizers in storage area	Examples: sodium dichromate, potassium permangenate, sodium periodate, sodium hypochlorite, benzoyl peroxide
Corrosive Acids (solids & liquids)	Store within dedicated acid cabinet. Use secondary containers particularly hazardous acids such as hydrofluoric acid. Separate inorganic and organic acids. Aqueous solutions < 2 M and weak, non-corrosive acids are exempt.	Examples: sulfuric acid, hydrochloric acid, acetic acid
Corrosive Bases (solids & liquids)	Store within dedicated caustic cabinet. Aqueous solutions < 2 M are exempt and weak, non-corrosive bases are exempt.	Examples: sodium hydroxide, ammonium hydroxide

Non-flammable solvents & regulated chemicals	Store with secondary containment on lab shelves or in cabinet. Includes carcinogens, teratogens, mutagens	Examples: dichloromethane, dimethylformamide
Low-hazard solids & liquids	Store on lab shelves or in cabinet. Includes weak acids and bases.	Examples: calcium chloride, sodium bicarbonate, copper sulphate

*Chemicals should be stored based on the first suitable grouping listed above.

12.4 PARTIAL LIST OF INCOMPATIBLE CHEMICALS

The following list is intended as a limited guide only. Refer to the appropriate MSDS for chemical incompatibilities not included in the following table.

Table 8: Partial List of Incompatible Chemicals

CHEMICAL	IS INCOMPATIBLE WITH:
Acetic acid	Chromic acid, nitric acid, alcohols, ethylene glycol, perchloric acid, peroxides, permanganates
Acetic anhydride	Hydroxyl-containing compounds e.g. ethylene glycol, perchloric acid
Acetone	Concentrated nitric and sulfuric acid mixtures, hydrogen peroxide
Acetylene	Chlorine, bromine, fluorine, copper, silver, mercury
Alkali and alkaline metals e.g. sodium, potassium, lithium, magnesium, calcium, powdered aluminum	Water, carbon tetrachloride and other halogenated alkanes, carbon dioxide, halogens
Aluminum Alkyls	Water
Ammonia, anhydrous	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrogen fluoride
Ammonium nitrate	Acids, powered metals, flammable liquids, chlorates, nitrates, sulfur, fine-particulate organic or combustible materials.
Aniline	Nitric acid, hydrogen peroxide
Arsenic compounds	Reducing agents
Azides	Acids
Bromine	Ammonia, acetylene, butadiene, butane, methane, propane, hydrogen, other petroleum gases, benzene, powered metals
Calcium oxide	Water
Carbon, activated	Calcium hypochlorite, oxidizing agents
Carbon tetrachloride	Alkali and alkaline metals e.g. sodium
Chlorates	Ammonium salts, acids, powered metals, sulfur, fine-particulate organic or combustible substances
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane, hydrogen, other petroleum gases, benzene, powered metals
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulphide
Chromic acid	Acetic acid, naphthalene, camphor, glycerol, turpentine, alcohols, flammable liquids
Copper	Acetylene, hydrogen peroxide
Cumene Hydroperoxide	Organic and inorganic acids
Cyanides	Acids

CHEMICAL	IS INCOMPATIBLE WITH:
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Fluorine	Store separately
Hydrazine	Hydrogen peroxide, nitric acid, oxidizing materials
Hydrocarbons, flammable (butane, propane, benzene, etc.)	Fluorine, chlorine, bromine, chromic acid, peroxides
Hydrocyanic acid	Nitric acid, alkalis
Hydrogen fluoride	Ammonia, aqueous or anhydrous
Hydrogen peroxide	Copper, chromium, iron, metals and metals salts, flammable liquids, aniline, nitromethane, combustibles (solid or liquid)
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Iodine	Acetylene, ammonia (anhydrous or aqueous)
Mercury	Acetylene, ammonia
Nitric Acid, Conc.	Acetic acid, acetone, aniline, chromic acid, prussic acid, hydrogen sulfide, flammable liquids and gases, nitratable substances e.g. copper, brass, heavy metals, organic products e.g. wood, paper
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic Acid	Silver, mercury and their salts
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohols, paper, wood, oils
Peroxides, organic	Mineral or organic acids
Phosphorus (white)	Sulfur, air, oxygen-containing compounds such as chlorates
Phosphorus pentoxide	Alcohols, strong bases, water
Potassium	See alkali metals
Potassium chlorate	See chlorates
Potassium perchlorate	See chlorates
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver and silver salts	Acetylene, oxalic acid, tartaric acid, ammonium compounds.
Sodium	See alkali metals
Sodium nitrate	Ammonium nitrate and other ammonium salts
Sodium peroxide	Methanol, ethanol, glacial acetic acid, anhydride, benzaldehyde, carbon disulfide, glycerol, ethylene glycol, ethyl acetate, methyl acetate, furfurol
Sulfides	Acids
Sulfuric acid	Lithium, sodium, potassium, chlorates, perchlorates, permanganates

CHEMICAL	IS INCOMPATIBLE WITH:
Tellurides	Reducing agents

12.5 CONTAINMENT

Care should be taken to ensure that chemicals/reagents/samples/solutions etc. are stored to minimize the risk of spills.

- Primary storage containers should be of a composition to maintain their structural integrity throughout the lifespan of the material they are holding through normal storage and use.
- Secondary containment should be used in all storage locations. This is containment (over-packs, spill trays, etc.) used in addition to the primary container to prevent release of material to the environment in the event that the primary container fails.

13. Fumehoods and Biological Safety Cabinets

Fumehoods and biological containment cabinets are critical pieces of laboratory equipment. If used and maintained properly, they are the most effective engineering control in protecting laboratory personnel against exposure to hazardous materials.

13.1 CHEMICAL FUMEHOODS

All work involving hazardous chemicals should be performed in an appropriate chemical fumehood. Figure A shows a diagram of a typical fumehood system. Diagram taken July 11, 2006 from: http://web.princeton.edu/sites/ehs/labsafetymanual/sec6b.htm#fhalv.

Figure A – Diagram of Typical Fumehood System

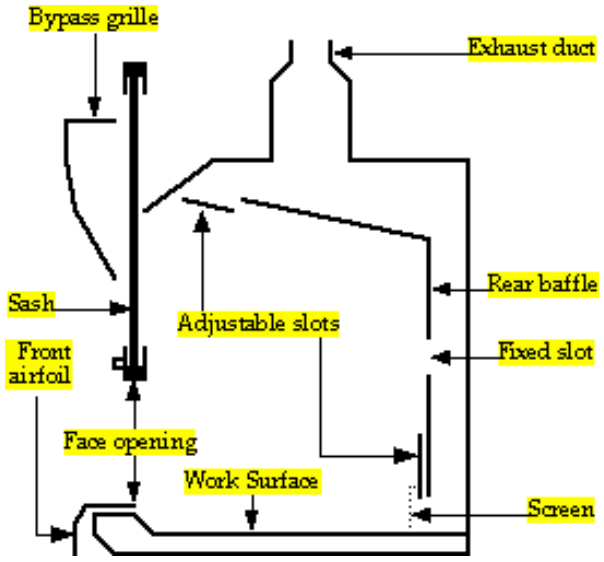


Table 9 shows a description of the types of chemical fumehoods/ventilation systems used throughout the University.

Table 9: Use and Characteristics of Different Types of Laboratory Ventilation Systems

TYPE	DESCRIPTION	PURPOSE
Standard	Face velocity increases as the sash is lowered. Air flow is directed to the outside through duct work.	Standard use.
Perchloric acid	Fumehood is lined with explosion resistant materials. Either standard or bypass ventilation systems.	Use with perchloric acid only.
Self-contained	Air flows through activated charcoal filter and is recirculated into lab environment.	Suitable only for moderate work with substances with low toxicity/hazards. The purchase and use of these hoods is strongly discouraged.
"Elephant trunk" ventilating systems	Overhead, often moveable, constant flow systems that provide ventilation at very specific locations.	Suitable for moderate bench work with compounds of low toxicity/hazards, placement over instrument exhaust vents, etc.

It is recommended that for normal use, fumehoods have face velocities of 80-100 fpm with a sash opening of 12" to ensure effective protection from the materials being used. Face velocities less than or significantly greater than this may limit the applications of the particular hood. SHERM coordinates a program for annual calibration and testing of fumehood air flow alarms.

Physical Resources is responsible for routine preventative maintenance of fumehood exhaust fans. This includes inspection of pulleys, belts, alignment, flexible connections, dampers and operation of the fan as well as greasing of fan bearings and motor bearings as applicable. Parts are replaced as required. If a problem with fumehood ventilation is identified, contact your local Physical Resources department; see the contact list at the beginning of this manual.

13.2 BIOLOGICAL SAFETY CABINETS

Biological safety cabinets are designed to protect people and the environment from contamination by micro-organisms and to prevent contamination of the samples/cultures within the cabinet. The units have high efficiency particulate air (HEPA) filters to clean the supply and exhaust air.

Generally biological containment cabinets should not be used for chemicals as they may have lower face velocities, recirculate the air within the cabinet itself which could lead to the build-up of fumes, and consist of filters that are not suitable for the collection of chemical vapours.

Refer to the Biosafety Manual for detailed information on types, use, operation and maintenance of biological containment cabinets.

13.3 PROPER USE OF FUMEHOODS/BIOLOGICAL SAFETY CABINETS

As noted above, chemical fumehoods and biological safety cabinets are the primary source of protection against hazardous materials. For these critical pieces of equipment to be effective the user must:

- Ensure the ventilation exhaust system is operational and that the face velocity is acceptable for the intended use.
- Minimize the sash opening for maximum protection.
- Avoid storing chemicals/equipment in the fumehood/cabinet, as this restricts the air flow. Flammable solvents/reagents must not be stored in the fumehood/cabinet.
- Avoid blocking the baffle(s); place equipment on legs if possible to maintain effective airflow.
- Work a minimum of 10 cm into the fumehood/cabinet.
- Never work in a fumehood/cabinet that is in alarm.
- Ensure that the fumehood/cabinet is not cluttered.
- Ensure that all waste, reagents, solvents and samples are sealed when not being used.
- Ensure that all electrical connections are outside of the fumehood/cabinet.
- Ensure that the fumehood/cabinet is kept clean and neat.
- Always close the sash when not in use.

14. Hazardous Waste Disposal

Disposal of hazardous waste is regulated through the provincial Ministry of the Environment (MOE). Hazardous wastes are never to be flushed down the drain or left to evaporate in a fumehood.

Hazardous waste disposal is managed through SHERM. Waste is picked up directly from laboratories. Refer to Laurier's "Hazardous Chemical Waste Procedure" on the SHERM website www.wlu.ca/sherm under "Laboratory Safety".

Hazardous waste disposal fees are considerable. There is no cost to the labs or departments for waste disposal, except in the following cases:

- Waste disposal costs resulting from lab "clean-ups";
- Disposal of atypical wastes e.g. explosives, PCBs, compressed gases etc.

14.1 MINIMIZING HAZARDOUS WASTE

In keeping with environmental responsibility, it is important to minimize waste generation. The following points may be of assistance:

- Buy only what you need.
- Miniaturize experiments.

- Choose non-hazardous substances over hazardous substances (e.g. use digital or ethanol-based thermometers over mercury-based thermometers).
- Return unused material to the supplier if possible (e.g. gas cylinders).
- Redistribute usable materials.
- Recycle/recover materials when this can be accomplished efficiently, effectively and safely.

14.2 PACKAGING AND LABELLING REQUIREMENTS

The generator of waste is responsible for providing appropriate waste containers and for ensuring that all hazardous waste is packaged and labelled appropriately. The following guidelines should be followed:

- Incompatible materials may not be combined in a single waste container.
- Chemical liquid waste containers may not to be filled beyond approximately 75% of their capacity to allow for vapour expansion.
- Container materials must be compatible with the contained wastes (e.g. hydrofluoric acid cannot be stored in glass containers; corrosives may not be stored in metal containers).
- Containers must be in good condition.
- Wastes must be identified appropriately (e.g. biohazard bags may not be used for chemical wastes if no biohazard exists).
- Non-hazardous wastes must be segregated from hazardous waste streams to avoid unnecessary expenses.
- Hazardous waste containers must be labelled with the first date that waste was added to the container. As per provincial legislation waste may not be kept for longer than 3 months.
- Hazardous waste must be clearly labelled with the identity of the waste and the generator of the waste.

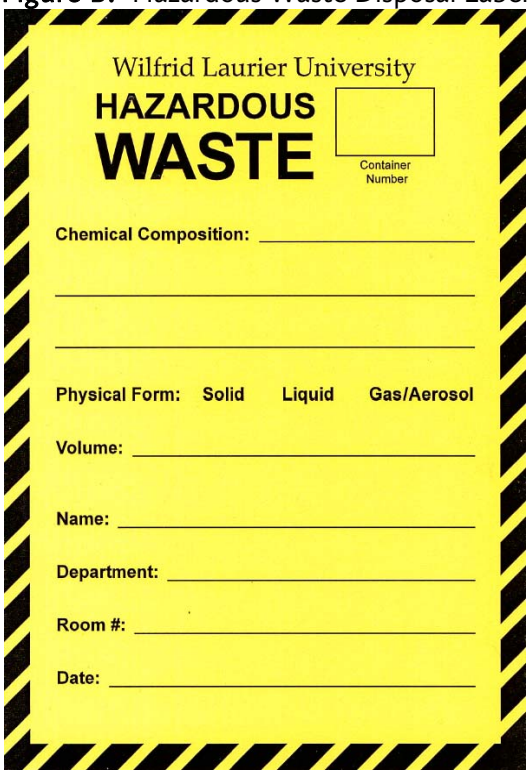
14.3 CHEMICAL WASTE

Hazardous chemical waste is picked up regularly by a hazardous waste contractor. Note that consumer products such as cleaning solvents, paints, paint thinners, oils and pesticides must be disposed as hazardous waste.

If you have waste for disposal:

- Complete a hazardous waste disposal label and attach it to waste containers. See Figure B for a sample hazardous waste label.

Figure B: Hazardous Waste Disposal Label



For details on hazardous waste disposal please refer to the SHERM website at www.wlu.ca/sherm under "Laboratory Safety" and "Hazardous Chemical Waste".

14.3.1 Unknown Waste

Waste of unknown composition will not be picked up by the hazardous waste contractor. It is the responsibility of the laboratory supervisor to identify or categorize the "unknown".

14.4 BIOHAZARDOUS WASTE

Refer to the Biosafety Manual for details.

14.5 RADIOACTIVE WASTE

Refer to the Radiation Safety Manual for details.

14.6 SHARPS WASTE

Any item with corners, edges or projections that are capable of cutting or piercing the skin is considered a sharp. Sharps must be separated from regular waste streams to prevent unnecessary needlestick injuries and/or lacerations. Sharps must be collected into puncture and leak proof containers. Details on sharps waste can be found in the standard operating procedure titled "Sharps Waste Management" on the SHERM website under "Laboratory Safety".

14.6.1 Broken Laboratory Glassware

Clean broken glassware, including Pasteur pipettes and broken laboratory glassware, must be separated into an appropriately marked glass waste container. Custodial staff will remove glass waste once the containers are full.

Contaminated broken glassware must be packaged and labelled according to the contaminant.

14.6.2 Syringes, Needles, Scalpels and Blades

- Dispose of syringes, needles, scalpels and blades in standard "Sharps" containers.
- When a container is full, autoclave according to CCME guidelines for biomedical waste (i.e. 120°C at 105 kPa for more than 60 minutes). If autoclaving is not possible, the container will be disposed of through the hazardous waste contractor. Contact SHERM at ext. 3108 for details.

14.7 BATTERIES

Waste batteries can be deposited into receptacles for recycling that are located in various departments on campus. For a list of locations and instructions for disposal, refer to www.wlu.ca/sherm under "Environmental Management".

15. Chemical Spill Prevention and Preparedness

Prevention of chemical spills is critical to any work involving chemicals. However, laboratory personnel should be aware of spill clean-up procedures and be prepared to respond should a spill occur.

15.1 TRAINING

It is the responsibility of the laboratory supervisor to ensure that lab personnel are trained in appropriate chemical spill response specific to the chemicals contained within their laboratory. Training should be documented and renewed as deemed necessary by the supervisor.

15.2 SPILL KITS

Each laboratory using hazardous chemical materials must have easy access to a chemical spill kit that is prominently located, readily visible and identifiable. A spill kit may be shared between laboratories provided that all personnel are aware of its location and that it is easily accessible at all times. Specific contents of a spill kit should be based on the hazardous properties and volumes of the materials present in the lab(s). Table 10 lists the recommended minimal requirements for spill kits.

Table 10: Minimum Requirements for Chemical Spill Kits.

Item	Characteristics and/or Recommended Quality

Universal Chemical Absorbent Pads
 	
and/or
 	
Universal Chemical Absorbent Powder (silica free)
	• High absorption capacity
	• Chemically inert
	• Good for all chemicals
	  o Acids, including HF
	  o Bases
	  o Flammable liquids
	  o Formaldehyde
	  o Organic peroxides

Personal Protective Equipment	• Gloves (Nitrile and Neoprene) – 2 pairs • Chemical goggles – 2 pairs • Coveralls – 2 pairs • Chemical cartridge respirator with multiple cartridges • Chemical resistant apron
Clean-up Equipment	• Large Polyethylene Bags When emptied to be used as disposal container for contaminated absorbents • Plastic dust pan and broom (Polypropylene bristles)
Plastic Container with Lid	• Labelled as “SPILL KIT”

	• To contain spill equipment • When emptied to be used as disposal container for contaminated absorbents • Leak proof

Other items to consider adding to your chemical spill kit depending on the hazards present in the lab are:

- Disposable Tyvek® suits;
- Duct tape;
- pH paper;
- Waste tags; and

When using acid or base neutralization mixtures one should be prepared for heat generation and sputtering of the liquid.
If mercury or mercury compounds are present in the laboratory (including mercury in thermometers) a mercury spill kit must be available. Table 11 lists the recommended contents for a mercury spill kit.

Table 11: Mercury Spill Kit Contents

Item	Characteristics and/or Recommended Quality
Sulphur powder or commercially available mercury amalgamation powder	• Effectively amalgamates mercury and suppresses vapours
Mercury vapour suppression spray	• Prevents further mercury vaporization
Mercury decontamination liquid, wipes or sponges	• For surface decontamination
Aspirator	• Could be a Pasteur pipette and bulb
Disposal container with lid	• Preferably plastic
Mercury indicator powder (optional)	• Indicates presence of mercury • Good for suspected contamination issues and for use after clean-up

It is recommended that an inventory list be included on/in spill kits to allow for easy inspection. Inspections should be performed regularly and documented (e.g. on an inspection tag). Inspections should include verification of contents and ensuring that supplies are not expired and are in good condition.

15.3 SPILL CLASSIFICATION

Major spills – These are spills that require further assistance for clean-up. Major spills involve chemicals or quantities of materials in excess of those outlined in Table 12:

Table 12: Guidelines for Classification of a Major Spill

Material	Quantity
Air and water reactive materials	All quantities
Flammable liquids	Greater than 4L
Combustible liquids	Greater than 4L
Non-flammable organic liquids	Greater than 4L
Concentrated acids	Liquids greater than 1L Solids greater than 1 kg
Concentrated bases and alkalis	Liquids greater than 1L Solids greater than 1 kg
Mercury	Greater than 30 mL
Oxidizers	Liquids greater than 1L Solids greater than 500g
Highly toxic, highly malodorous materials (e.g. phenol, mercaptoethanol, hydrofluoric acid)	Liquids greater than 100 mL Solids greater than 50g
Low hazard material	At the discretion of laboratory personnel
Compressed gas leaks	If the leak cannot be stopped by closing the valve on the gas cylinder
Radioactive materials	See Radiation Safety Manual

The table above provides *guidelines for quantities only*. Other considerations for classifying a spill as major include whether respiratory protection is required, whether the material is unknown, and whether personal injuries have been sustained.

Laboratory personnel should never attempt to clean up a spill if they have not been trained in the proper chemical spill response or if they are unsure of the proper procedures.

Minor Spills – These are spills that can be cleaned up by trained laboratory personnel, and do not meet the criteria for a major spill, above.

15.4 SPILL RESPONSE

Response to a Major Spill:

- Evacuate the lab, close doors, restrict the area, and notify others in the area of the spill.
- Call Special Constable Service.
- Activate fire alarm if there is risk to the safety of other people in the building.

- Be available to provide technical information to emergency responders, e.g. identify of the spilled chemical(s), MSDS, identity of other equipment and hazardous materials in the lab.

Response to a Minor Spill:

- Attend to injured or contaminated personnel.
- Restrict the area and notify others in the lab of the spill.
- Take action to minimize the effects of the spill.
- If a flammable material is involved, turn off ignition sources (i.e. shut off power to area, turn off Bunsen burners etc.)
- Select and wear all appropriate personal protective equipment.
- It is the responsibility of the user of the hazardous material to clean up the spill, if he/she feels it is safe to do so.
- Apply spill pillow/pads or other absorbent material, first around the outside of the spill, encircling the material, then absorb to the center of the spill.
- All personal protective equipment must be disposed of correctly, and must not be worn outside the laboratory.
- Dispose of all materials used to clean up the spill in a sealed container.
- Label and dispose of all bags or containers as hazardous waste. If you are unsure of the proper clean-up procedure, contact your supervisor for guidance. SHERM is also available to provide guidance at ext 3108.

15.5 OTHER SITUATIONS

Chemical spill on the body:

- Remove all contaminated clothing.
- Flood exposed area with running water from a safety shower for at least 15 minutes.
- Have another individual contact the 9-911 and Special Constable Service to obtain medical attention.
- Report the incident to your supervisor.

Chemical splashed in the eye(s):

- Immediately rinse eyeball and inner surface of eyelid with water continuously for 15 minutes. Forcibly hold eye lid(s) open to ensure effective wash behind eyelids.
- Have another individual contact 9-911 and Special Constable Service to obtain medical attention.
- Report the incident to your supervisor.

16. Laboratory Equipment and Procedures

Many pieces of laboratory equipment can be hazardous if not used and maintained appropriately. Personnel should be trained in the use of laboratory equipment prior to using the equipment. General precautions for the use of some apparatus are provided in the following sections. Specific operational instructions provided in manufacturer's instruction manuals and in-lab standard operating procedures must be followed. These manuals/procedures should be located with the equipment or otherwise easily accessible. Maintenance or repairs on any laboratory equipment should be performed only by competent personnel trained and qualified to perform such work. Safety devices on laboratory equipment must not be disabled.

16.1 ATOMIC ABSORPTION SPECTROMETERS

Sample preparation for atomic absorption (AA) procedures often requires handling flammable, toxic and corrosive products. Use the MSDS and/or other suitable reference and follow the recommended safety precautions. Atomic absorption equipment must be adequately vented, as toxic gases, fumes and vapours are emitted during operation. Other precautions for carrying out atomic absorption analysis are as follows:

- Wear safety glasses suitable for protection against impact.
- Inspect the integrity of the burner, drain and gas systems prior to use.
- Allow the burner head to cool to room temperature before handling.
- Avoid viewing the flame or furnace during atomization unless wearing protective eyewear.
- Handle hollow cathode lamps with care, as they are under negative pressure. Dispose of hollow cathode lamps as hazardous waste to minimize implosion risks.

16.2 AUTOCLAVES

Autoclaves present potential burn and explosion hazards due to high temperature and pressure. Prior to using an autoclave, users must receive training on safe use and adhere to the user guidelines and standard operating procedures.

- Autoclaves are inspected annually by a qualified inspector and must have a certificate of inspection prior to use.
- The inspection certificate is to be posted in a conspicuous location near the autoclave.
- Inspections and tests are to be performed by trained, qualified personnel.
- Autoclaves must be equipped with a safety/pressure release valve set at or below the maximum pressure of the autoclave.
- PPE to be worn when loading or unloading an autoclave, as follows:
    - heat insulating gloves;
    - goggles and a face shield if a splash hazard exists;
    - splash apron; and
    - closed-toed shoes.

- Oils, waxes, certain plastics, flammable materials, radioactive materials and samples containing substances that may emit toxic fumes may not be autoclaved.
- Ensure that lids to all containers are loosened to prevent pressure build-up during heating and a vacuum on cooling.
- Ensure that containers of liquid are no more than 2/3 full.
- Use secondary containment to prevent spillage (i.e. put items in trays that will catch spills should they occur).
- When unloading the autoclave:
    - ensure that the autoclave has depressurized prior to opening the door.
    - stand to the side of the autoclave, away from the door and crack open the door approximately 1" to allow steam to escape and pressure within liquids and containers to normalize
    - let autoclaved items stand for at least 10 minutes
    - open the door and carefully remove the items from the autoclave, transferring them to a safe location where they can cool completely. Superheated liquids can 'bump" when they are removed from the autoclave causing a spray of boiling liquid if proper containers aren't used.
- If the autoclave becomes non-functional, label it as such and initiate maintenance/repairs as appropriate and in accordance with department policies.

16.3 BLENDERS, GRINDERS AND SONICATORS

When used with infectious agents, mixing equipment such as shakers, blenders, grinders, sonicators and homogenizers can release significant amounts of hazardous aerosols, and should be operated inside a biological safety cabinet whenever possible. Do not use flammable solvents in equipment such as blenders and stirrers as they can also produce a large amount of flammable vapours.

- Ensure equipment has safety features that will minimize leaking and prevent operation if blades are exposed.
- Ensure that any equipment that could move during use is secured to a bench or the floor as applicable.
- Ensure equipment is in good condition prior to use.
- Allow aerosols to settle for at least one minute before opening containers.

16.4 CENTRIFUGES

Safe use of centrifuges requires proper maintenance and operation. Failed mechanical parts or improper operation can result in release of projectiles, hazardous chemicals and biohazardous aerosols. Maintenance and repairs must be performed only by trained, qualified personnel.

To maintain your safety, sample integrity and the equipment:

- Ensure that centrifuges have an interlocking device that will prevent both the lid from being opened when the rotor is in motion and the centrifuge from starting when the lid is open

- Ensure that centrifuge tubes are free of hairline cracks, stress lines and chipped rims prior to use.
- Ensure that tube materials are chosen such that they provide the necessary chemical resistance and speed rating.
- Avoid over-filling tubes.
- Cap or stopper centrifuge tubes.
- Use sealed centrifuge buckets (safety cups) or rotors that can be loaded and unloaded in a biological safety cabinet or chemical fumehood as appropriate.
- Decontaminate the outside of the cups/buckets and rotors before and after centrifugation.
- Inspect o-rings regularly and replace if they are cracked or dry.
- Ensure that the centrifuge is properly balanced. Load the rotor with samples arranged symmetrically. Opposing tubes must be of equal weight. If necessary, use "water blank" tubes to balance sample tubes of unequal weight. Do not use sight or volume to conclude that tubes are balanced. Use an electronic balance to balance tubes before using them in an ultracentrifuge.
- Ensure that the prescribed speed limitations of the rotor or centrifuge are never exceeded.
- Unless fitted with a suitable exhaust system, do not centrifuge materials capable of creating flammable or explosive vapours.
- Remain with the centrifuge until it has reached its programmed speed.
- Abort the run immediately if you hear abnormal vibration, whining or grinding noises. Check the rotor lid and balance.
- At the end of the run ensure that the rotor and centrifuge are cleaned according to manufacturer's instructions. Never use abrasive cleaners.
- Rotors are easily damaged. Never use metal tools to remove tubes or clean the rotors.
- If the centrifuge is connected to a vacuum pump, ensure that the pump exhaust is connected to a trap.
- If biohazardous materials are being centrifuged and the centrifuge is connected to a vacuum pump, ensure that a HEPA filter is installed between the centrifuge and the vacuum pump.

16.5 ELECTROPHORESIS

The use of voltages of approximately 200 V and currents of more than 80 mA in electrophoresis procedures could create the potential for an electrical shock if the equipment is not operated properly.

- Use physical barriers to prevent inadvertent contact with the equipment.
- Ensure that electrophoresis equipment is properly grounded.
- Inspect electrophoresis equipment regularly for damage and potential buffer tank leaks.
- Locate equipment away from high traffic areas and away from wet areas such as sinks or washing apparatus.
- Use of ground fault circuit interrupters is recommended.
- Display warning signs to identify the electrical hazards (i.e. "Danger – High Voltage").

- Turn off power before connecting leads, opening the lid or reaching into the chamber.
- Ensure that lead connectors are insulated.

16.6 GAS CHROMATOGRAPHS

Gas chromatography (GC) procedures involve the use of compressed gas cylinders and may involve the use of flammable solvents and toxic chemicals. Be familiar with the use and handling of compressed gas cylinders, with hazardous properties, precautionary measures, and handling instructions for any hazardous materials being used. Refer to MSDSs and/or other reliable reference material. The following guidelines will assist in the safe operation of GCs:

- Wear proper eye protection. GC columns are fragile and breakage could result in small projectiles during handling. As well, samples are prepared in various hazardous solvents that could damage the eyes upon contact.
- When cutting a GC column, be sure that the cut is made away from the body.
- Ensure that GC column cutters are capped or otherwise stored to prevent injury when not in use.
- Discard small pieces of GC columns as sharps waste.
- Ensure that the oven is allowed to cool before installing or removing a column or injector or prior to performing maintenance.
- Ensure that gases are turned off prior to removing or installing a column.
- Test for leaks after the installation of the column and whenever a leak is suspected. Use a technique that will not damage or sacrifice the integrity of the instrument.
- Electron capture detectors (ECD) have a radioactive source and therefore need to be registered as part of the University's Radiation Safety program. ECDs may not be relocated or discarded without permission of the Radiation Safety Officer. Contact the Radiation Safety Officer at extension 3108 for more information about Canadian Nuclear Safety Commission (CNSC) requirements.
- Ensure that the instrument and gases are turned off and the power cord disconnected prior to performing maintenance.

16.7 GLASSWARE

Improper use of glassware can lead to many injuries in the laboratory.

- Use only the right size and type of glassware for any given operation.
- Ensure that glassware is in good condition prior to use (i.e. no cracks, chips, significant scratches).
- Discard broken glassware in appropriate containers, i.e. biohazardous sharps container if contaminated with biohazards.
- Cut glass tubes/tubing by scoring using a file or equivalent. Cover the glass with a piece of cloth and break at the score over a piece of cloth/paper to catch any pieces.
- Wear leather or other cut-resistant gloves when inserting glass tubing into a stopper or flexible tubing. Fire polish tubing ends and lubricate glass to make the connection easier. Ensure that stopper holes are appropriately sized and carefully insert tubing by carefully twisting back and forth.

- Wear leather gloves when removing glass tubing from flexible tubing or a stopper. If difficult, carefully cut with a scalpel blade or other appropriate glass cutter. Ensure that cuts are made away from the body.
- Ensure glassware is stored away from the edges of benches so that it cannot easily be knocked over.

16.8 GLOVE BOXES/GLOVE BAGS

Gloves boxes and bags are isolated, fully sealed containment units fitted with armholes and gloves so highly toxic or pyrophoric materials can be manipulated safely:

- Generally glove boxes are operated under positive pressure so that any leakage is out of the box. However, if operated under negative pressure to maintain a dry and/or anaerobic environment *and* highly toxic materials are being used, sufficient leak testing is required prior to use.
- If a glove box is used with highly toxic materials, the exhaust is to be treated prior to release to the environment. Contact SHERM at ext. 3108 for guidance in this situation.

16.9 HEATING BATHS

Heating baths are designed to heat materials to constant temperature. They may be filled with a variety of materials including water, mineral oil, sand, glycerin, paraffin or silicone oils, depending on the bath temperature required. Bath temperatures may range up to 300°C. The following are precautions for heating baths:

- Locate on a stable surface, away from flammable and combustible materials including wood and paper.
- Ensure liquid has cooled before moving the heating bath.
- Do not fill over the “full mark”.
- Ensure baths are equipped with controls that will turn off the power if the temperature exceeds a preset limit.
- Ensure that the thermostat is set well below the flash point of the heating liquid in use.
- Equip the bath with a non-mercury thermometer to allow a visual check of the bath temperature.
- Take care not to allow water to get into oil baths as violent splattering may result.

Steam baths are often safe alternatives for heating because they provide a consistent temperature that will not exceed 100°C. However, care must be taken to prevent scalding due to dermal exposure to the steam or steam lines.

Water baths are the most common bath found in the laboratory. When using a water bath:

- Clean the bath regularly; a disinfectant, such as a phenolic detergent, can be added to the water.
- Decontamination can be performed by raising the temperature to 90°C or higher for 30 minutes once a week.
- Unplug the unit before filling or emptying.

16.10 HIGH PERFORMANCE LIQUID CHROMATOGRAPHS

High performance liquid chromatography (HPLC) procedures often require handling of flammable and toxic solvents. Refer to MSDSs and/or other reliable reference material. The following guidelines will assist in the safe operation of HPLCs.

- Wear appropriate eye protection. Since the HPLC is operated at high pressures, it is possible for fittings to fail, resulting in a sudden release of solvent.
- Use "elephant trunk" ventilating system above fraction collectors, especially with normal phase HPLC.
- Inspect and empty the waste containers as required.
- Ensure that waste collection vessels are vented.
- Ensure secondary containment of waste containers.
- 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 and autosampler. Switch off the electrical power and disconnect the power cord when performing routine maintenance.

16.11 HYDROGENATORS

When used properly, commercially available hydrogenators allow hydrogenation reactions performed at elevated pressures using various catalysts to be carried out safely:

- Ensure that the apparatus is appropriate for the specific reaction to be performed.
- Inspect the reaction vessel prior to each use to ensure that there are no scratches, chips, etc. that would make them unsuitable for use in high pressure experiments.
- Ensure that oxygen is removed from the reaction solution before the introduction of hydrogen.
- Ensure that the safe pressure limit of the vessel is not approached as pressure will increase with heating.
- At the end of the reaction, purge the system repeatedly to prevent the production of a hydrogen-oxygen mixture.
- Take particular care to ensure that catalysts are not allowed to dry once filtered from reaction mixtures as they are usually saturated with hydrogen and may spontaneously ignite on exposure to air. Filter cakes should be immediately transferred to water and purged with an inert gas such as nitrogen or argon.

16.12 LASERS

The use of lasers and the corresponding management of their hazards must comply with ANSI Z136.1. The hazards associated with the use of Class 3B or 4 lasers include eye or skin burns, fire and electrocution. All Class 3B and Class 4 lasers must be registered with the Laser Safety Officer. Refer to Laurier's Laser Safety Program for further details.

Below are key aspects of laser hazard management:

- Ensure that operation, repair and maintenance are performed only by competent, trained and qualified personnel.
- Ensure that appropriate protective eyewear and protective clothing are worn as determined by the class of the laser.
- Manufacturer installed safety devices such as shields or interlocks must not be altered, disconnected or removed without written approval from the laboratory supervisor.

Contact the Laser Safety Officer at extension 3108 for more information.

16.13 MASS SPECTROMETERS

Mass spectrometers (MS) require the handling of compressed gases and flammable and toxic chemicals. Be familiar with the use and handling of compressed gas cylinders, the hazardous properties, recommended precautionary measures, and handling instructions for any hazardous materials being used. Refer to MSDSs or other reliable reference material. Specific precautions for working with the mass spectrometer include:

- Avoid contact with heated parts while the mass spectrometer is in operation.
- Inspect 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 must be handled as hazardous waste.

16.14 NUCLEAR MAGNETIC RESONANCE SPECTROMETERS

Nuclear magnetic resonance spectrometers (NMRs) use superconducting magnets, thereby introducing hazards related to high-strength magnetic fields and cryogenic liquids (i.e. liquid nitrogen and liquid helium, which are used for cooling). Improper operation of the instrument or improper activities near the instrument could lead to significant personal injury or death, costly equipment damage and loss of data.

- Ensure that warning signs are posted at or beyond the 5-gauss line indicating the hazards, The 5-gauss line is the distance from the centre of the magnet where a magnetic field strength of 5 gauss is present, and where the field strength is strong enough to act upon objects.
- Individuals with medical devices (e.g. cardiac pacemakers and metal prostheses) must remain outside the 5-gauss line. The magnetic fields generated are strong enough to affect the operation and integrity of some of these medical devices.
- Keep ferromagnetic materials outside the 5-gauss perimeter. Strong magnetic fields surrounding the NMR attract objects containing steel, iron, and other ferromagnetic materials. This includes most ordinary tools, electronic equipment, compressed gas cylinders, steel chairs, and steel carts. Unless restrained, such objects can suddenly fly toward the magnet which can cause personal injury and extensive damage to the NMR.

Only non-ferromagnetic materials should be used near the instruments. If in doubt, keep it out!

- Floppy disks, tapes, cards with magnetic strips, cellular phones, laptops and mechanical watches should remain outside the 5-gauss perimeter. Strong magnetic fields can damage the strip of magnetic media found on credit cards, ATM cards, driver's licenses, and other cards. Floppy disks, tapes, cellular phones, and laptop computers are also susceptible to damage inside this perimeter. Mechanical wrist and pocket watches will also malfunction and be permanently damaged when exposed to a strong magnetic field.
- If damaged, the magnet may quench. Leave the room immediately. A quench refers to the sudden release of gases from the dewar. Rapid expansion of liquid helium or nitrogen to gas can displace breathable oxygen in an enclosed space, creating the possibility of asphyxiation. Do not re-enter the room until the oxygen level has returned to normal.
- Only qualified, trained and competent personnel may complete helium or nitrogen fills, due to the hazards and precautions associated with the use of cryogenic liquids. Appropriate protective equipment including a minimum of safety glasses and gloves must be worn.
- During variable temperature experiments, do not exceed the boiling or freezing points of your sample. A sample subjected to a temperature change can build up excessive pressure, which can break the tube. Ensure safety glasses are worn near the magnet when performing variable temperature experiments.
- Inspect NMR sample tubes prior to use and discard any tubes that are cracked, chipped, scratched or otherwise in poor condition.
- Use care when handling NMR sample tubes as they are very fragile.
- Do not operate the NMR in the presence of flammable gases or fumes.
- Do not look down the upper barrel of an NMR if a probe is in place. Pneumatic ejection of a sample from the probe could cause injury.
- Take care that solvents used for sample preparation will not undergo unwanted reactions with the analyte.

16.15 OVENS, HOT PLATES AND HEATING MANTLES

Ovens are commonly used in the lab to evaporate water from samples, provide a stable elevated environment and to dry glassware. Heating mantles are used to heat reaction or sample solutions in round-bottom flasks or reaction vessels, and hot plates are used to heat various general laboratory solutions. Bunsen burners may be used only after obtaining approval from the supervisor. The following precautions should be followed to ensure safe use:

- Ensure that laboratory ovens and hot plates are designed to prevent contact between flammable vapours and heating elements/spark-producing components.
- Avoid heating toxic, even mildly volatile materials in an oven unless it is continuously vented outdoors.
- Glassware that has been rinsed with an organic solvent is to be rinsed with distilled water or equivalent before being placed in an oven for drying.
- Hot plates or ovens whose thermostat fails must be removed from service until repaired. Heating devices whose temperature rises above that required could create significant fire hazards.

- Heating mantles must be used in conjunction with a variable autotransformer; care must be taken not to surpass the maximum voltage of the mantle recommended by the manufacturer.
- Discontinue use of any heating mantle where the heating elements have become exposed.

16.16 ULTRAVIOLET LAMPS

Exposure to ultraviolet light (UV) may result in serious and painful injury to the eyes or skin depending on the wavelength and intensity of the light and the duration of exposure.

- Label all UV light sources conspicuously with the following warning (or equivalent): "Warning – this device produces potentially harmful UV light. Protect eyes and skin from exposure."
- Ensure that the UV light source is shielded.
- Ensure that appropriate PPE is worn and is sufficient to protect the eyes and skin. PPE should include at least UV resistant face shield, gloves, and lab coat.
- Shielding the equipment or the work area may be warranted.

17. Electrical Safety

17.1 GENERAL

Use of electrical equipment must be in accordance with the Safe Management of Electrical Applicances Program that can be found on the SHERM website, www.wlu.ca/sherm under "General Topics" and "Electrical Safety". General guidance for electrical safety in the laboratory is provided below:

- Report defects/faults to your supervisor.
- **All electrical apparatus must be properly grounded.**
- **Never remove the ground pin of a 3-pronged plug.**
- Inspect electrical cords regularly and have frayed or damaged cords replaced.
- Extension cords must only be used as a temporary solution.
- "Piggy-backing" of extension cords is prohibited.
- Never use a power bar beneath workbenches where chemicals are handled.
- **DO NOT** use electric wires as supports and never pull on live wires.
- Ensure that all wires are dry before plugging into circuits.
- **Electrical devices (unless certified explosion-proof) should be connected outside of the hood** to avoid sparks which may ignite a flammable or explosive chemical.
- Use of Ground Fault Interrupter Circuits (GFCI) is preferable in receptacles located near sinks.
- Circuit breaker panels within laboratories must be easily accessible and clearly marked. Familiarize yourself with their location.

- Only qualified and trained people should repair or modify electrical or electronic equipment.

Any electrical equipment purchased, regardless of voltage, must be approved as indicated by the presence of a field approval mark from the Canadian Standards Association (CSA), Electrical Safety Authority (ESA), or an equivalent field approval mark acceptable under the Electrical Safety Code i.e. Ontario Hydro (OH), International Approval Services (IAS) or Intertek Testing Services. The cost of the Electrical Safety Authority field approvals and modifications, if required, is the responsibility of the acquiring department.

17.2 STATIC ELECTRICITY AND SPARKS

Static electricity and sparks may cause a fire under the right circumstances. Always be conscious of the potential for generating sparks.

- Electrical equipment must have spark protection in areas where there is a danger of fire or explosion.
- Some protection from static electricity and sparks is obtained by proper grounding and bonding of containers and equipment.
- A dry atmosphere promotes the formation of electrical charges.
- Common sources of sparks and static electricity are:
    - decanting of organic liquids from one metal container to another
    - plastic aprons
    - metal clamps, nipples or wires used with non-conducting hoses
    - gases released quickly from cylinders under high pressure
    - switches and thermostats
    - electrical contacts (eg. light switches and thermocouples, refrigerators) may produce sparks

Appendix A: Unattended Procedures Form

Experiment Run Date(s): _____

Supervisor/PI: _____ Phone: _____

After-hours Emergency Contact: _____ Phone: _____

Description of Experiment or Procedure	
Equipment involved	
Sources in use: (describe briefly)	
Electrical	
Nitrogen	
Vacuum	
Water	
Other	
Specific Hazards: (describe briefly)	
Corrosive	
Flammable	
Oxidizer	
Toxic	
Other	
Special Warning	

This form must be posted at the location of an experiment conducted while no laboratory personnel are present, i.e. after business hours or on weekends. A notice with the phrase "UNATTENDED PROCEDURE IN PROGRESS" along with the name and phone number of the emergency contact must also be posted on the laboratory entrances.

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Safety, Health, Environment & Risk Management (SHERM)

SHERM is committed to promoting an environmentally responsible, safe and healthy work environment for all community members, while striving to ensure compliance with relevant regulations and support the University's mission of teaching and research.

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