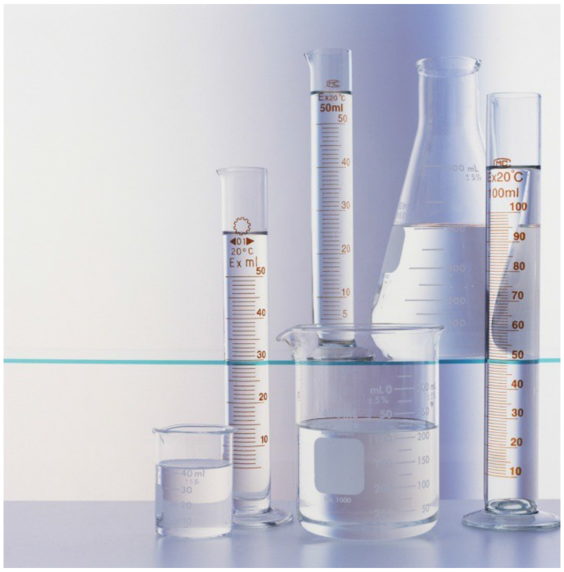
UNIVERSITY of GUELPH

CHANGING LIVES
IMPROVING LIFE

ENVIRONMENTAL
HEALTH & SAFETY



Laboratory Safety Manual

4th edition 2016

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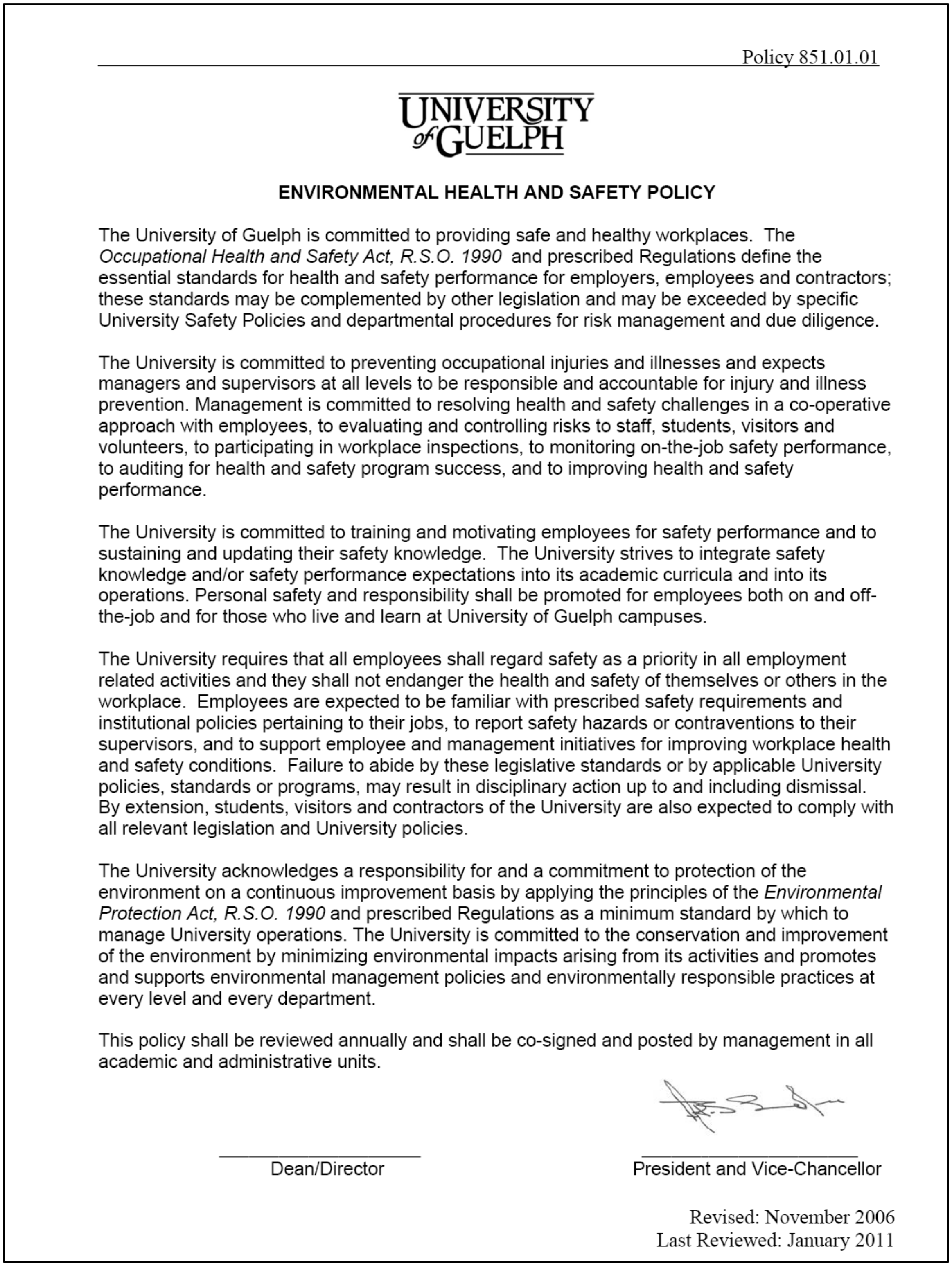


Policy 851.01.01

UNIVERSITY
of GUELPH

ENVIRONMENTAL HEALTH AND SAFETY POLICY

The University of Guelph is committed to providing safe and healthy workplaces. The *Occupational Health and Safety Act, R.S.O. 1990* and prescribed Regulations define the essential standards for health and safety performance for employers, employees and contractors; these standards may be complemented by other legislation and may be exceeded by specific University Safety Policies and departmental procedures for risk management and due diligence.

The University is committed to preventing occupational injuries and illnesses and expects managers and supervisors at all levels to be responsible and accountable for injury and illness prevention. Management is committed to resolving health and safety challenges in a co-operative approach with employees, to evaluating and controlling risks to staff, students, visitors and volunteers, to participating in workplace inspections, to monitoring on-the-job safety performance, to auditing for health and safety program success, and to improving health and safety performance.

The University is committed to training and motivating employees for safety performance and to sustaining and updating their safety knowledge. The University strives to integrate safety knowledge and/or safety performance expectations into its academic curricula and into its operations. Personal safety and responsibility shall be promoted for employees both on and off-the-job and for those who live and learn at University of Guelph campuses.

The University requires that all employees shall regard safety as a priority in all employment related activities and they shall not endanger the health and safety of themselves or others in the workplace. Employees are expected to be familiar with prescribed safety requirements and institutional policies pertaining to their jobs, to report safety hazards or contraventions to their supervisors, and to support employee and management initiatives for improving workplace health and safety conditions. Failure to abide by these legislative standards or by applicable University policies, standards or programs, may result in disciplinary action up to and including dismissal. By extension, students, visitors and contractors of the University are also expected to comply with all relevant legislation and University policies.

The University acknowledges a responsibility for and a commitment to protection of the environment on a continuous improvement basis by applying the principles of the *Environmental Protection Act, R.S.O. 1990* and prescribed Regulations as a minimum standard by which to manage University operations. The University is committed to the conservation and improvement of the environment by minimizing environmental impacts arising from its activities and promotes and supports environmental management policies and environmentally responsible practices at every level and every department.

This policy shall be reviewed annually and shall be co-signed and posted by management in all academic and administrative units.

____
Dean/Director

____
President and Vice-Chancellor

Revised: November 2006
Last Reviewed: January 2011

1. Introduction

Providing a safe and healthy place to work and study is of utmost importance to the University. Researchers in the laboratories at the University of Guelph conduct extensive research as well as provide valued educational opportunities to thousands of undergraduate and graduate students over a broad spectrum of disciplines. In order to address the health, safety and environmental challenges specific to the laboratories, this manual, encompassing guidelines and procedures have been developed.

This manual is to provide supplemental information to the University of Guelph and departmental health and safety policies as well as define *minimum* standards for safe practices in the University's research, service and teaching laboratories.

Our goal is a safe and healthy environment for faculty, staff, students and visitors.

2. Definitions

The Act – Ontario Occupational Health and Safety Act.

competent person – means a person who,

- is qualified because of knowledge, training and experience to organize the work and its performance;
- is familiar with the Act and the regulations that apply to the work; and
- has knowledge of any potential or actual danger to health or safety in the workplace. (ONTARIO OH&S ACT SECTION 1(1))

due diligence – taking *all* precautions reasonable in the circumstance to protect the health and safety of the worker.

EHS – Environmental Health and Safety.

incident – an event that results in injury to people and/or damage to the environment, equipment, property and/or material.

injury – an event that results in physical harm to an employee.

laboratory – for the purposes of this manual, a laboratory is considered to be any space where scientific research, experimentation or analysis is conducted. Computer "labs" are excluded from this definition.

laboratory personnel – any employee, student or visitor conducting scientific research, experimentation or analysis within a laboratory.

near miss – an event that under different circumstances could have resulted in physical harm to an individual or damage to the environment, equipment, property and/or material.

OHW – Occupational Health and Wellness.

research laboratory – a laboratory designed primarily for research.

service laboratory – a laboratory providing contracted analysis or experimental procedures for another agency either within or outside of the University usually for a fee, e.g. Laboratory Services Division.

supervisor – a person who has charge of a workplace or authority over a worker. (ONTARIO OH&S ACT SECTION 1(1))

teaching laboratory – a laboratory designed with an instructional function related to a University course for students.

3. Training

It is the responsibility of supervisors to ensure that:

- *All* laboratory personnel have received sufficient introduction and training on specific equipment, procedures and materials in the laboratory where they will be working.
- All training is documented with the documentation maintained for all personnel.

In addition to project specific training, the supervisor is responsible for ensuring that new personnel are oriented and made aware of emergency and safety procedures including, but not limited to, emergency evacuation routes, emergency or safety procedures specific to the laboratory as well as departmental safety policies and procedures and applicable policies and procedures included in the Laboratory Safety Manual and the University of Guelph Health and Safety Policies.

Supervisors are to ensure that all new laboratory personnel have successfully completed all applicable courses as prescribed in the EHS Training Matrix **prior** to beginning applicable work (i.e. Lab Safety and WHMIS training is to be completed prior to working in the lab, Radiation Safety training is to be completed prior to working with radioisotopes).

These courses are offered via on-line and/or in-class formats. See the Environmental Health and Safety website for more information on course offerings.

It is the responsibility of the supervisor to ensure that all training of laboratory personnel is documented and maintained throughout the employment of the worker or until graduation of a student.

4. Incidents

4.1 Incident Reporting

All incidents and near misses are to be reported to Occupational Health and Wellness (OHW) the Injury/Incident Report form (http://www.uoguelph.ca/ehs/forms/incident-report-form). In order to meet regulatory requirements, these forms are to be submitted to OHW within 24 hours with the exception of critical injuries which are to be called into **EHS** immediately. After hours, EHS can be contacted through Campus Community Police at extension 52000. Critical injuries are those injuries that meet at least one of the following criteria:

- places life in jeopardy;
- produces unconsciousness;
- results in substantial loss of blood;
- involves fracture of a leg or arm but not a finger or toe;
- involves amputation of a leg, arm, hand or foot, but not a finger or toe;
- consists of burns to a major portion of the body; or
- causes the loss of sight in an eye. (R.R.O. 1990, REG. 834 AS AM. O. REG351/91)

Employees should seek first aid at or near the location of the injury. First aid stations for the Guelph Campus are:

- Occupational Health and Wellness, Alexander Hall Room 179
- Student Health Services, J.T. Powell Building
- Campus Police/Fire Prevention, 24-hour, mobile service accessed through x2000

If there is any health concern following an incident, follow up with medical professions should be initiated:

For employees, contact OHW x 54283

For students, contact Student Health Services x 52131

Follow-up may include medical assessment and/or surveillance. Additional details regarding incident reporting can be found in Safety Policy 851.04.02.

4.2 Incident Investigation

Many lessons can be learned from incidents and near misses. Incident investigation is an important component of the continuous improvement of safety practices and procedures. However, to be effective, the active participation of supervisors and workers is essential. Investigations are intended to uncover *contributing factors* and *root causes*, which may not be immediately evident upon initial review of the incident. It is essential that the scene of an accident is preserved so that a thorough and accurate investigation can be performed. Scenes of critical injuries must *legally* be preserved until permission for clean-up is given from the Ministry of Labour inspector and, if applicable, law enforcement personnel.

In order to thoroughly investigate an incident, consider the following strategies:

- Consider both why it happened and why the situation wasn't prevented or detected before it became an incident or near-miss.
- Continue to ask "why" until you drill down to detail that can no longer be broken down.
- Consider all possible contributing elements. The following categories should be considered:
  - personnel (e.g. personnel appropriately trained? competent?);
  - machinery (e.g. was equipment operating appropriately? maintenance up to date?);
  - methods (e.g. were procedures appropriate for the application and were they being followed appropriately?);
  - environment (e.g. housekeeping, lighting, physical condition of the workplace); and
  - materials (e.g. hazardous materials involved, personal protective equipment).

EHS personnel are available to assist in investigations and will perform their own investigations as necessary.

5. WHMIS 2015 – the "NEW" Workplace Hazardous Materials Information System

The Workplace Hazardous Materials Information System (WHMIS) is a legislated program that is applicable to all University of Guelph employees and students who work in areas where hazardous materials are used. The purpose of this legislation is to ensure that everyone in a workplace is provided with the information needed to identify hazardous materials and to take the appropriate precautions when working with these materials. WHMIS accomplishes this through the use of warning labels, Material Safety Data Sheets (MSDSs)/Safety Data Sheets (SDSs) and training on how to use the information provided.

What is GHS?

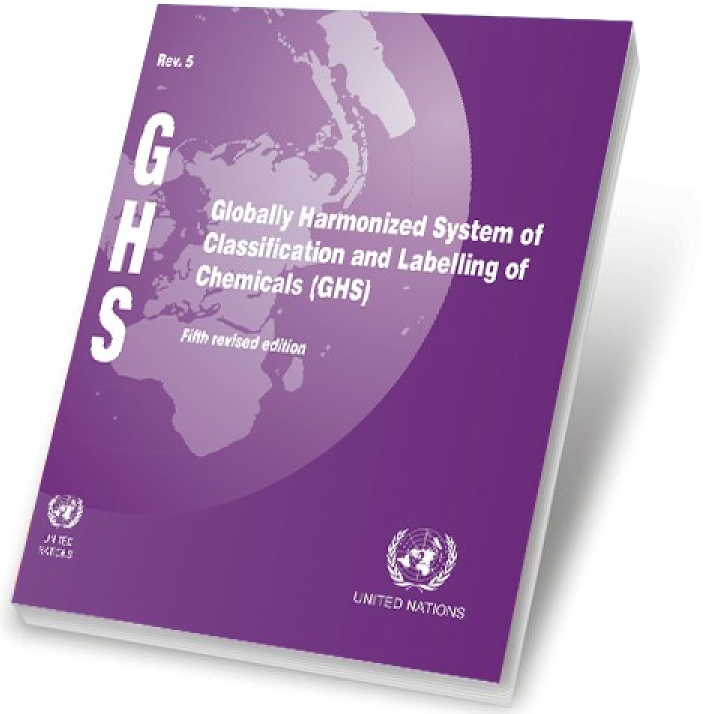
GHS is an international initiative to standardize chemical hazard classification and communication globally. The implementation of GHS in WHMIS helps harmonize hazard communication systems worldwide and provides set of guidelines for ensuring the safe production, transport, handling, use and disposal of hazardous materials

WHMIS is a national hazard communication system that provides information on the safe use of hazardous materials in Canadian workplaces. **GHS doesn't replace WHMIS**. WHMIS will be modified to incorporate the GHS elements with standardized;

- chemical classification rules
- label requirements
- safety data sheet (SDS) format (formerly material safety data sheet (MSDS)

The GHS has more detailed and comprehensive criteria which results in expanded hazard categories and improved communication of hazards to workers. The resulting harmonization is expected to maintain/enhance worker protection while reducing barriers to trade among countries.

www.osha.gov/dsg/hazcom/ghs.html



. What is GHS expected to do?

The goal of the GHS is to identify hazards found in substances and mixtures and to communicate hazard information about these hazards.

To achieve this, the criteria for hazard classification are matched and the hazard statements, symbols, and signal words have been standardized to form an integrated hazard communication system.

For example:

- GHS labels are the main communication tool for consumers
- GHS is similar to existing transport requirements where containers will be marked with pictograms that address acute toxicity, physical hazards, and environmental hazards. However, signal words and hazard statements requirement haven’t been adopted by the transportation sector
- All GHS elements are to be adopted in the workplaces, including harmonized labels, safety data sheets and employee training

The anticipated transition period for the complete WHMIS2015 implementation is 3 years. Until December 1, 2018, users may expect to see BOTH, old WHMIS labels and MSDSs and WHMIS2015 labels and SDSs. After that time, all chemicals will be labelled with the WHMIS2015 labels and all MSDSs will be replaced by SDSs.

WHMIS2015 - Hazard Classification, Group, Class and Category

Hazard Classification

With the adoption of GHS, the greatest changes are associated with hazard classification and hazard communication. The hazard classification is based on the following principles:

Pure substances - classification is based on the following:

- Results of reference methods of testing
- Results of testing or studies carried out in accordance with generally accepted standards
- Data from case reports or documented observation

Mixtures – classification is based on the following:

- Test data for all substances
- Calculations and concentration limits
- Synergistic and antagonistic effects

Hazard Group

There are two major groups of hazards under WHMIS 2015: physical, and health.

Each hazard group includes hazard classes that have specific hazardous properties.

- **Physical hazards group** is based on the physical or chemical properties of the substance (for example flammability, reactivity, or corrosivity)

- **Health hazards group** is based on the ability of the product to cause a health effect - such as eye irritation, respiratory sensitization (may cause allergy or asthma symptoms or breathing difficulties if inhaled), or carcinogenicity (may cause cancer).

You may also see the Environmental classes listed on labels and Safety Data Sheets (SDSs). The could include Explosives, Hazard to the Aquatic Environment and Hazard to the Ozone Layer. Including information about environmental hazards is allowed by WHMIS 2015 but not mandatory.

Hazard Classes

Hazard classes are a way of grouping substances with similar properties. Most of the hazard classes will be used worldwide by all countries that have adopted GHS. However, some hazard classes are specific to WHMIS 2015 (Canada).

There are two recognized hazard Classes: Physical Hazard Classes and Health Hazard classes, both of which have subclasses as described in the following sections.

Physical Hazards Classes:

All GHS physical hazard classes, except the Explosives hazard class, have been adopted in Canada. In addition, a few new physical hazard classes have been introduced to enhance protections for workers: Combustible Dusts, Simple Asphyxiants, Pyrophoric Gases and Physical Hazards Not Otherwise Classified.

Combustible Dust
Corrosive to Metals
Flammable Aerosols
Flammable Gases
Flammable Liquids
Flammable Solids
Gases under Pressure
Organic Peroxides
Oxidizing Gases
Oxidizing Liquids
Oxidizing Solids

Pyrophoric Gases
Pyrophoric Liquids
Pyrophoric Solids
Self-Heating Substances and Mixtures
Self-Reactive Substances and Mixtures
Simple Asphyxiants*
Substances and Mixtures Which, in Contact with Water, Emit Flammable Gases
Physical Hazards Not Otherwise Classified*

Retrieved from WHMIS.org (with modifications)

Health Hazard Classes:

Health hazard classes introduce some additional types of hazards that are not included in "old" WHMIS but enhance protections for workers.

Acute Hazards	**Chronic Hazards**
Acute Toxicity (LD50 and LC50)	**Respiratory or Skin Sensitization**
Aspiration Hazard	**Germ Cell Mutagenicity**
Biohazardous Infectious Materials*	**Carcinogenicity**
Serious Eye Damage and Irritation	**Reproductive Toxicity and Lactation Effects**
Skin Corrosion and Irritation	**Target Organ Toxicity - Repeated Exposure**

Health Hazards Not Otherwise Classified*	**Target Organ Toxicity - Single Exposure**
Acute Toxicity (LD50 and LC50)	**Health Hazards Not Otherwise Classified***

The Biohazardous Infectious Materials hazard class was retained in Canada to maintain worker protection, and a new Health Hazards Not Otherwise Classified class has also been introduced.

Hazard Category

The hazard classes are further divided into categories. Categories are assigned a number (from 1 to 5). Some hazard classes have only one category (e.g., corrosive to metals), others may have two categories (e.g., carcinogenicity (cancer)) or three categories (e.g., oxidizing liquids). There are a few hazard classes with five or more categories (e.g., organic peroxides).

In a few cases, sub-categories are also assigned and are identified with a number and a letter (e.g., 1A and 1B).

For example:

- Category 1 is always the greatest level of hazard which means it is the most hazardous within that class). If Category 1 is further divided, Category 1A within the same hazard class is a greater hazard than category 1B.
- Category 2 within the same hazard class is more hazardous than category 3, and so on.

There are a few exceptions to this rule. For example, for the Gases under pressure hazard class, the hazard categories are "Compressed gas", "Liquefied gas", "Refrigerated liquefied gas" and "Dissolved gas". These classes relate to the physical state of the gas when packaged and do not describe the degree of hazard.

> In addition, the Reproductive Toxicity hazard class has a separate category called "Effects on or via lactation". "Effects on or via lactation" was not assigned a specific numbered category. Reproductive toxicity also has Categories 1 and 2 which relate to effects on fertility and/or the unborn child.

5.1 Labels

The label is the primary source of hazard information. The requirements for label content are dependent upon whether the container is from a supplier or a workplace, and whether the hazardous material is a laboratory product, a sample for analysis or neither.

5.1.1 Supplier Labels

A supplier label is required for containers from the supplier containing 100 mL or more of the material.

There are two main types of WHMIS2015 labels: supplier label, and workplace label.

A supplier label is developed and attached to a container by the supplier and will appear on all hazardous products received at a workplace.

A workplace label is required when:

- a hazardous product is produced at the workplace and used in that workplace,
- a hazardous product is decanted (e.g., transferred or poured) into another container, or
- a supplier label becomes lost or unreadable.

There are two situations when a workplace label is **not** necessary. When a hazardous product is:

- poured into a container and it is going to be used immediately, or
- when it will remain under the control of the person who decanted it. For example, when the person who poured the product into another container will be the only person who will use it and the product will be used during one day. **However**, the container must still be identified with the product identifier (name). If the product is not used right away or if more than one person will be in control of the product, a full workplace label is required.

WHMIS 2015 supplier labels must be bilingual, easy to read, and the pictograms, signal words and hazard statements must be grouped together on a label.

“old” WHMIS (1988)	WHMIS2015
Product identifier	Product identifier
Supplier identifier	Supplier identifier
Symbol	**Pictogram**
Risk phases	**Hazard statement**
NA	**Signal word**
Precautionary measures	Precautionary measures
First Aid statement	Part of precautionary measures
Hatched border	**Red square border**

Signal word

There are only two signal words used: "**Danger**" or "**Warning**".

- "Danger" is used for high risk hazards
- "Warning" is used for less severe hazards.

If a signal word is assigned to a hazard class and category, it must be shown on the label, and listed in section 2 (Hazards Identification) of the Safety Data Sheet (SDS). – see unit 8.

Some hazard classes or categories do not have a signal word assigned to them.

Hazard Statement

Each hazard class and category has also an assigned hazard statement. Hazard statement are brief, standardized sentences that inform the user about the hazard of the product. Although the statements are short, they describe the most significant hazards of the product.

Here is an example of the supplier label under “old” WHMIS

METHANOL

DANGER

POISON
FLAMMABLE
VAPOUR HARMFUL
MAY CAUSE BLINDNESS IF SWALLOWED

Keep away from heat, sparks and flame. No smoking. Container must be grounded when being emptied. Vapour may travel long distance. Avoid contact with eyes and skin. Do not inhale vapours or mist. Do not take internally. Harmful if absorbed through the skin.

FIRST AID: In case of contact, immediately flush eyes and skin with plenty of water for at least 15 minutes.

If swallowed, induce vomiting by sticking finger down throat, or by giving soapy water to drink. Repeat until vomit is clear.

If affected by vapour, move to fresh air.

If breathing has stopped, apply artificial respiration.

GET MEDICAL ATTENTION IMMEDIATELY.

PRECAUTIONS: Wear chemical-goggles and resistant gloves. Wash thoroughly after handling. Use with enough ventilation to keep below TLV. Keep container closed. Never use pressure to empty container.

MÉTHANOL

DANGER

POISON
INFLAMMABLE
VAPEURS NOCIVES
PEUT PROVOQUER LA CÉCITÉ, SI AVALÉ

Garder loin de la chaleur, des étincelles et des flammes. Ne pas fumer. Brancher le contenant à une prise de terre avant de le vider de son contenu. Les vapeurs peuvent s'étendre sur de longues distances. Éviter tout contact avec les yeux et la peau. Ne pas respirer les vapeurs. Ne pas absorber. Nocif si absorbé par la peau.

PREMIERS SOINS: En cas de contact avec les yeux ou la peau, laver à grande eau pendant au moins 15 minutes.
Si avalé, provoquer le vomissement en introduisant un doigt dans la gorge ou en faisant absorber de l'eau savonneuse à la victime. Répétez jusqu'à cessation du vomissement.

Sortir au grand air, si indisposé par les vapeurs.

Si la respiration est interrompue, recourir à la respiration artificielle.

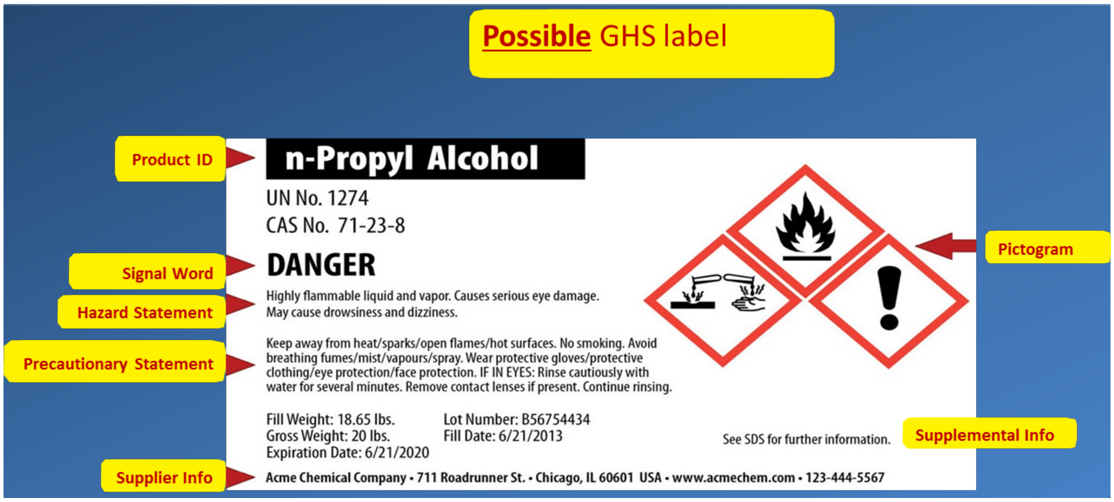
OBTENIR DES SOINS MÉDICAUX IMMÉDIATS.

PRÉCAUTIONS: Porter des lunettes protectrices (pour produits chimiques) et des gants résistants. Se laver minutieusement après usage. Utiliser dans un endroit bien aéré, afin de maintenir un niveau de vapeurs tolérable. Garder le contenant fermé. Ne jamais user de pression en vidant le récipient.

SEE MATERIAL SAFETY DATA SHEET FOR PRODUCT
VOIR FICHE SIGALÉTIQUE

ABC Company
Anytown, Ontario Telephone 123-4567

And WHMIS2015



n-Propyl Alcohol

UN No. 1274
CAS No. 71-23-8

DANGER

Highly flammable liquid and vapor. Causes serious eye damage.
May cause drowsiness and dizziness.

Keep away from heat/sparks/open flames/hot surfaces. No smoking. Avoid breathing fumes/mist/vapours/spray. Wear protective gloves/protective clothing/eye protection/face protection. IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present. Continue rinsing.

Fill Weight: 18.65 lbs.
Gross Weight: 20 lbs.
Expiration Date: 6/21/2020
Lot Number: B56754434
Fill Date: 6/21/2013

See SDS for further information.

Acme Chemical Company • 711 Roadrunner St. • Chicago, IL 60601 USA • www.acmechem.com • 123-444-5567

5.1.2 Workplace Labels

A workplace label must contain the following information:

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

5.1.3 aboratory Labels

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

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

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

Laboratory samples being submitted for analysis where the container holds less than 10 kg, require a label including:

- 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. For hazard information call ...."

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 within the laboratory where produced, need to be labelled with the product identifier only.

5.2 Material Safety Data Sheets and Safety Data Sheets

MSDSs (Material Safety Data Sheets) and SDSs (Safety Data Sheets) provide detailed information about physical, chemical and toxicological properties and hazards of the hazardous materials, as well as recommended handling and emergency procedures. In the past, Material Safety Data Sheets had to be reviewed or revised by the supplier at least every three years.

SDSs no longer have to be updated every 3 years but rather within 90 days when new information or scientific data for the chemical is available.

What Are the 16 Sections of an SDS?

If no relevant information is found for any given subheading within a section, the SDS shall clearly indicate that no applicable information is available. Sections 12-15 may be included in the SDS, but are not mandatory.

1. Identification

- Product identifier used on the label;
- Other means of identification;
- Recommended use of the chemical and restrictions on use;
- Name, address, and telephone number of the chemical manufacturer, or importer
- Emergency phone number.

2. Hazard(s) identification

- Signal word, hazard statement(s), symbol(s) and precautionary statement(s)
- Describes any hazards not otherwise classified that have been identified during the classification process;

3. Composition/ information on ingredients

SUBSTANCES

- Chemical name (including common name and synonyms)
- Chemical Abstracts System (CAS) registry number
- Chemical name of the impurities and stabilizing additives which contribute to the classification of the substance.

MIXTURES

In addition to the information required for substances:

- The chemical name and concentration (percentage) or concentration ranges of all ingredients which are classified as health hazards or are present above their concentration limits; or present a health risk below the cut-off/concentration limits.

- The concentration (percentage) shall be specified unless a trade secret claim is made, or when there is batch-to-batch variability in the production of a mixture

4. First-aid measures

- Description of necessary measures, subdivided according to the different routes of exposure, i.e., inhalation, skin and eye contact, and ingestion;
- Most important symptoms/effects, acute and delayed.
- Indication of immediate medical attention and special treatment needed, if necessary.

5. Fire-fighting measures

- Suitable (and unsuitable) extinguishing media.
- Specific hazards arising from the chemical

6. Accidental release measures

- Personal precautions, protective equipment, and emergency procedures.
- Methods and materials for containment and cleaning up.

7. Handling and storage

- Precautions for safe handling.
- Conditions for safe storage, including any incompatibilities.

8. Exposure controls/personal protection

- Appropriate engineering controls
- Individual protection measures, such as personal protective equipment

9. Physical and chemical properties

For example: Appearance, Odor, pH, Flash point, Flammability, Incompatible materials etc.

10. Stability And Reactivity

- Description of conditions under which the material is unstable or can react dangerously and conditions that should be avoided.
- Description of unstable materials that might decompose and cause fires or explosions

- Physical conditions such as heat, sunlight, or aging of the chemical that may cause unstable chemicals to break down.

11. Toxicological information

- Information on the likely routes of exposure (inhalation, ingestion, skin and eye contact)
- Symptoms related to the physical, chemical and toxicological characteristics;
- Delayed and immediate effects and also chronic effects from short- and long-term exposure
- Numerical measures of toxicity (such as acute toxicity estimates)

12. Ecological information (**Non-mandatory**)

- Adverse effects (such as hazardous to the ozone layer).

13. Disposal considerations (**Non-mandatory**)

- Description of waste residues and information on their safe handling and methods of disposal

14. Transport information (**Non-mandatory**)

- UN number, UN proper shipping name, Transport hazard class, etc.
- Special precautions that a user needs to be aware of, or needs to comply with

15. Regulatory information (**Non-mandatory**)

- Safety, health and environmental regulations specific for the product

16. Other information

- The date of preparation of the SDS or last change to it

Up-to-date, electronic MSDS/SDSs are available via the EHS website. Printable access instructions are available via the EHS website.

Supervisors are to ensure that laboratory personnel are aware of and able to readily access these electronic MSDSs. Laboratory personnel are strongly encouraged to regularly review MSDSs for all hazardous materials being used.

5.3 Training

Training is required to provide detailed instruction on the site-specific procedures necessary to carry out work safely, as well as provide the basis for proper interpretation of hazard information provided on labels and MSDSs. Generic WHMIS training is provided via in-class and online formats through EHS. For training schedule and to register visit EHS Online Course Registration.

5.4 Understanding hazard warning information

5.4.1 WHMIS Symbols and Pictograms

The classes of controlled chemical products and their corresponding symbols or pictograms, as well as general characteristics and handling precautions are outlined in Table 1.

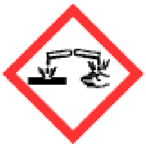
Table 1 – Summary of WHMIS classes, their associated characteristics and proper handling and storage procedures.

	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 , November 2005.

WHMIS2015 pictograms will eventually replace old WHMIS symbols.

	**Exploding bomb** (for explosion or reactivity hazards)		**Flame** (for fire hazards)		**Flame over circle** (for oxidizing hazards)
	**Gas cylinder** (for gases under pressure)		**Corrosion** (for corrosive damage to metals, as well as skin, eyes)		**Skull and Crossbones** (can cause death or toxicity with short exposure to small amounts)
	**Health hazard** (may cause or suspected of causing serious health effects)		**Exclamation mark** (may cause less serious health effects or damage the ozone layer*)		**Environment*** (may cause damage to the aquatic environment)
	**Biohazardous Infectious Materials** (for organisms or toxins that can cause diseases in people or animals)				

* The GHS system also defines an Environmental hazards group. This group (and its classes) was not adopted in WHMIS 2015. However, you may see the environmental classes listed on labels and Safety Data Sheets (SDSs). Including information about environmental hazards is allowed by WHMIS 2015.

FLAME

This pictogram identifies materials that will readily burn. These materials are:

- Flammables
- Pyrophorics
- Self-Heating
- Materials that emit flammable gas
- Self-Reactive's
- Organic peroxides

Exploding bomb

These are materials that are explosive. They include:

- Self-Reactive's
- Organic peroxides

NOTE*

Organic peroxides are listed under both the "flame" pictogram and the "exploding bomb" pictogram. Organic peroxides are unstable compounds that react differently based on the type of organic peroxide and its concentration. They easily decompose, producing heat as they decompose. Some may decompose slowly producing fumes that are combustible. Other organic peroxides may heat up as they decompose and be self-igniting or can be very unstable and can easily explode.

Skull and Crossbones

This is the symbol that will appear on the most severely toxic chemicals. Depending on the toxicity of the chemical, the skull and crossbones indicate that the chemical may be toxic or fatal.

Specifically it can mean:

- Fatal if swallowed
- Fatal in contact with skin
- Fatal if inhaled
- Toxic if swallowed
- Toxic in contact with skin
- Toxic if swallowed

Corrosion

A corrosive is a substance that will dissolve, destroy, or damage objects that are in contact with a corrosive substance and it is immediately dangerous to living tissues. Corrosives typically will dissolve metals and include acids, bases (such as alkalis), and oxidizers

Corrosives can cause:

- Burns
- Loss of skin and body tissues
- Eye damage

Gas Cylinder

Gases under pressure, Also known as compressed gas, present a number of dangers. Leak of a gas from a gas cylinder can send the cylinder rocketing through an area causing a physical hazards. Gas cylinders often contain flammable gases which present both a fire hazard and a possible explosion hazard should a cylinder leak. Cylinders may also contain oxidizers that react violently with other materials. Finally, cylinders can present invisible hazards. For example, cylinders may contain an inert gas such as nitrogen, helium or argon. Leaks from these cylinders can reduce oxygen levels such that people lose consciousness or die from asphyxiation.

Health Hazard

This is a general category that identifies materials that are harmful to human health. This symbol identifies materials that are capable of causing cancer (carcinogens) or mutations (mutagenicity). The types of materials that cause health hazards include:

- Carcinogens
- Mutagenicity
- Reproductive toxicity
- Respiratory sensitizer
- Toxic to specific organs
- Aspiration toxicity

Environment

This pictogram ide notifies materials that have a aquatic toxicity and thus are harmful to the environment. This pictogram should be used when appropriate.

Exclamation Mark

The exclamation mark provides a general warning about substances that are harmful.

This includes:

- Irritants (skin and eye)
- Skin sensitizers
- Acute toxicity (harmful)
- Narcotic effects
- Respiratory tract irritant
- Hazardous to ozone layer

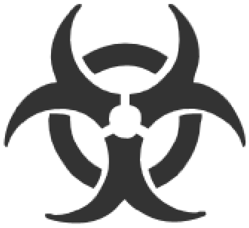
Flame Over Circle

This pictogram represents Oxidizers **-** substances that increase the burning of fuels (combustibles and flammables) by increasing the oxygen levels available to the fuels. Depending on the oxidizer, the substance may spontaneously start the fire or it may increase the burning of another substance, such as a combustible.

Examples:

- Organic peroxides: benzoyl peroxide
- Other oxidizers: concentrated nitric acid, sodium hypochlorite (bleach), oxygen, concentrated or heated perchloric acid, concentrated sulfuric acid, concentrated hydrogen peroxide

Biohazardous Infectious Materials



Biological hazards, also known as biohazards, refer to biological substances that pose a threat to the health of living organisms. This includes medical waste or samples of microorganisms, viruses or toxins that can affect human health. It can also include substances harmful to other animals.

5.4.2 oxicological properties: LD_{50} AND LC_{50}

Exposure to hazardous materials can occur by:

- absorption;
- ingestion;
- inhalation; or
- 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 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 administered by inhalation over a specified period of time, is expected to cause 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. For example sodium chloride (table salt) has an LD_{50} (oral, rat) of 3000 mg/kg and sodium cyanide has an LD_{50} (oral, rat) of 6.4 mg/kg.

5.4.3 Exposure values (TWAEV, STEV, CEV)

Exposure values are established concentrations that, if not exceeded, will not generally cause adverse health effects to the person exposed. 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)

5.4.4 lash point

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 of a substance, the greater the fire hazard. Common laboratory solvents such as acetone, toluene, acetonitrile and methanol all have flash points that are below room temperature.

5.4.5 toignition temperature

Autoignition temperature is the temperature at which a material will ignite, *in the absence* of an ignition source. The lower the autoignition temperature of a substance, the greater the fire hazard.

5.4.6 lammable limits

Flammable or explosive limits are the range of concentrations of a material in air that will burn or explode in the presence of an ignition source. 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 contains enough fuel, but insufficient oxygen.

The flammable range consists of concentrations between the LEL and the UEL.

Table 2 – Flash points, lower explosive limits, autoignition temperatures and exposure limits of several flammable or combustible laboratory solvents.

Solvent	Flash Point * (°C)	LEL * (% by volume)	Autoignition temp** (°C)	TWAEV * (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

TWAEV – 8 Hour Time Weighted Average Exposure Value
LEL – Lower Explosive Limit
*NIOSH Pocket Guide to Chemical Hazards, NIOSH publication number 2005-151
** Corresponding MSDS

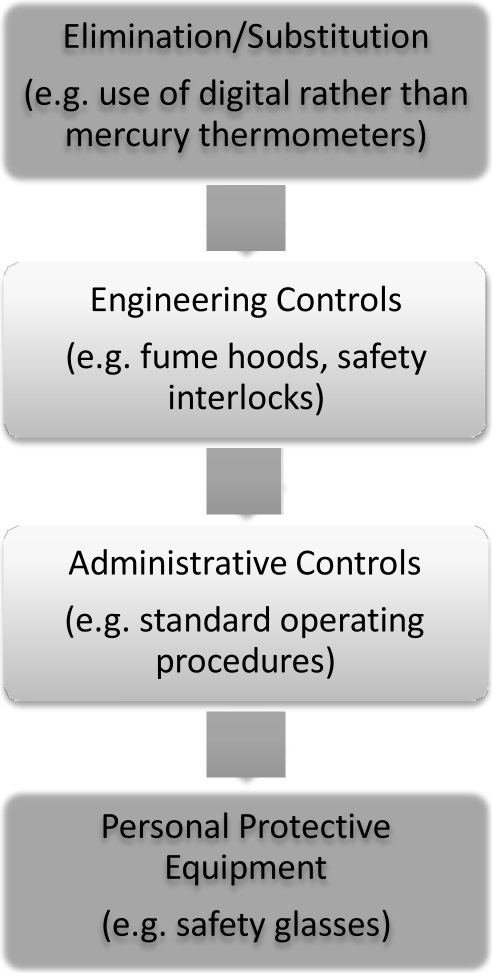
6. Hazard Identification and Control

A workplace hazard is any equipment, procedure, material, environment or situation that may cause personal injury or illness, or environmental or property damage. Management of hazards can effectively be accomplished through the following process:

Every effort should be made to anticipate hazards during the design stage of work in order to minimize the hazards that need to be managed. Workplace hazards are to be identified and evaluated based on the degree of risk and exposure using tools such as:

- Review of the experiment or process and the planned safety precautions;
- Detailed inspection and/or testing of the hazard;
- Physical observation by trained individuals;
- Investigations of near misses;
- Conducting interviews with workers;
- Reviewing records such as operating manuals, methods, injury reports or minutes of Joint Health and Safety Committee meetings.

Once the assessment of the hazard has been completed, appropriate control measures are to be implemented as appropriate to the situation. Below are control strategies, listed in order of effectiveness. The best controls are those that are mistake-proof, being effective independent of the worker, e.g. safety interlocks on centrifuges that prevent the lid from being opened until the rotor has stopped spinning. Management of hazards will often involve a combination of the following strategies.



7. General Laboratory Safety

7.1 Good Work Practices/General Safety

Lab work requires focus and undivided attention to ensure both that accidents are prevented and that proper actions are taken in the event of an emergency.

- 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.
- Avoid the use of personal audio devices and cell phones as these may disrupt concentration as well as prevent recognition of an emergency alarm, call for help etc.
- Report missing labels to laboratory supervisors. Never use substances of unknown identity.

- Consult your supervisor before proceeding with any aspect of your experimentation that you are unsure of (e.g. safe handling of material, operation of equipment, experimental technique etc
- Mouth pipetting is strictly prohibited.
- Avoid storage of personal belongings (e.g. bags, coats etc.) in the lab except in designated areas free of hazardous materials.
- Never “sniff-test” a chemical.
- Running, horseplay and practical jokes are prohibited.
- Report accidents and near misses promptly to your supervisor.

7.2 Housekeeping

Good housekeeping practices are essential in every workplace; however they become especially important in the laboratory environment where spills from broken reagent containers, sample bottles, reaction vessels, etc., can create unnecessary exposures 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 importantly, safe work environment. Ensure that:

- dirty glassware is cleaned on a regular basis and is not allowed to accumulate in sinks, on benches or in surrounding areas;
- reagents are stored appropriately when not in use;
- old or unused samples and reagents are disposed of in a timely manner;
- storage of materials or equipment does not obstruct aisles, fire extinguishers, safety showers, eye wash stations or other emergency equipment;
- items are kept away from the edge of bench tops so they cannot easily be knocked off;
- stored items, do not project beyond the front of shelf or counter limits;
- storage of large, awkward, heavy or breakable items on high shelves is avoided;
- experiments are cleaned up upon completion and that all work is tidied accordingly at the end of each day;
- apparatus used infrequently is stored appropriately when not in use;
- equipment no longer used is recycled or appropriately disposed;
- electrical cords, hoses, and air lines are secured.

7.3 Food storage and consumption

Storage and consumption of food and/or drink (including water) within the research, teaching or service laboratories is strictly prohibited. The use of laboratory equipment including, but not limited to, glassware, refrigerators, freezers, microwaves and other ovens etc., to store or prepare food is strictly prohibited. Ice from laboratory ice makers is not to be consumed.

7.4 Smoking

As per Policy 851.03.07, smoking is strictly prohibited in all University buildings including laboratories and in or near all chemical or waste storage areas. Tobacco products are not to be brought into the laboratory.

7.5 Personal Hygiene

To prevent unforeseen accidents or exposures, the following points are to be followed to ensure that particular attention is paid to personal hygiene while working in the laboratory.

- Tie back or otherwise secure long hair. This is important to prevent exposures from hazardous materials as well as to prevent the hair from becoming entangled in a moving part of equipment. This is also good practice to prevent contamination of research samples.
- Neck ties are to be removed or secured (preferably behind a lab coat).
- Avoid touching your face or hair while wearing gloves.
- Hands are to be washed thoroughly after removal of gloves and/or after working with hazardous materials.
- Application of cosmetics or lip balm in the lab is prohibited.

7.6 Working Alone

This section is to be used in conjunction with Policy 851.06.06. It is not advisable to conduct laboratory work alone. These situations present additional hazards to personnel as they may find themselves isolated and without help in the event of an emergency.

In the event that a true working alone situation is warranted and following a hazard review of the work to be done as well as a review of hazards in the laboratory itself, the supervisor may allow specific projects or tasks to be performed while working alone. The supervisor is to be made aware of dates, times and locations of all working alone situations. When working alone, laboratory personnel are encouraged to make arrangements to have someone check-in with them regularly either in person or by phone.

The following circumstances are **examples** of situations where working alone situations are prohibited:

- Work involving acutely toxic substances (e.g. sodium cyanide);

- Work involving dangerously reactive substances (e.g. peroxides, pyrophorics or water reactives);
- Hot work (i.e. work involving an open flame in a lab where flammable substances are present); and
- Work involving the use of highly corrosive substances (e.g. hydrofluoric acid).

7.7 Unattended Procedures

Certain instrumentation configurations are designed to routinely operate unattended, e.g. liquid and gas chromatographs equipped with autosamplers, centrifuges, autoclaves etc. However non-routine, unattended laboratory procedures should be minimized. If a procedure is to be left unattended, prior review of the hazards with consideration of the materials and procedures being used is to be completed. Only procedures that are deemed to be safe if left unattended are allowed to continue without personnel present in the laboratory. The following are requirements for non-routine unattended laboratory procedures.

- Unattended procedures are to be visited periodically and a sign posted outlining the procedure being used with the contact information of the person responsible for the work. The sign is to indicate the start date and time along with the expected completion date and time of the work. Sign templates are available on the EHS website.
- Unattended procedures using cooling water are to have hoses securely attached and the water adjusted to the minimum flow necessary. Ensure plumbing drains are clear before leaving the procedure.
- Unattended heating is only to be done using heating equipment that reliably maintains stable temperatures.
- If heating is being performed, flammable materials are to be removed from the area. This includes flammable hazardous wastes.
- Experiments should be miniaturized if possible.
- Sash doors are to be closed on all fume hoods.

7.8 Visitors in the laboratory

Due to the potential hazards present in laboratory settings, to protect the integrity of the research being performed and for security of the equipment and supplies contained within, visitors to laboratories should be escorted. Supervisors are responsible for considering and approving exceptions to this as appropriate. Careful consideration of the hazards is to be done prior to opening up a laboratory for the purposes of an open house. Should a laboratory be opened to the public, a representative of the laboratory should be present at all times.

Note that documented permission from a parent or guardian and departmental approval may be required for entrance of a minor into a laboratory, e.g. the “Take your kids to work” program. Contact EHS at x53282 for details.

8. Personal Protective Equipment

Personal protective equipment (PPE) is to be used according to the hazards presented in the specific laboratory as determined by the laboratory supervisor. Laboratory areas should be clearly labelled as to the personal protective equipment required, to ensure clear communication to any individual entering the area. Personal protective equipment is not to be used in place of engineering controls such as fume hoods, but is to be used diligently to provide supplemental protection.

This section provides minimum standards for personal protective equipment.

8.1 Eye and face protection

This section is to be used in conjunction with Policy 851.05.03. Canadian Standards Association (CSA) approved eye protection is to be worn by students, employees and visitors in all areas where hazardous or unknown substances (either chemical or biological) are being stored, used or handled, where there is a risk of splash, projectiles or air borne particles or where there is harmful radiant energy.

- Minimum eye protection worn in the laboratory consists of approved safety glasses with permanent side shields. Safety glasses are designed to protect against impact and do not provide significant splash protection. Therefore safety glasses should only be worn in cases of light work not involving significant volumes of liquids.
- Goggles are to be worn when there is a risk of splashing a hazardous material. Indirect vented goggles are preferred.
- Eye protection is to provide adequate impact and splash resistance appropriate for the work being done.
- Ultraviolet (UV) protective eyewear is required where there is risk of exposure to UV light.
- Face shields are to be used if an explosion or significant splash hazard exists such that there is a need to provide further protection to the face.
- Face shields are to be used in conjunction with primary eye protection (safety glasses or goggles depending on the hazard).

- Full size shields that can be placed directly in front of the hazard may also be used to provide additional protection to the entire body. These too, are only to be used in conjunction with goggles, lab coats, etc.

While wearing contact lenses is not prohibited in laboratories, an assessment of the specific circumstance or environment is to be made to decide whether or not wearing contact lenses presents a hazard to the worker and therefore if it should be prohibited. Contact lenses themselves do not provide eye protection. Further information regarding the wearing of contact lenses in laboratory situations may be found at the following websites:

Canadian Centre for Occupation Health and Safety – OSH Answers: http://www.ccohs.ca/oshanswers/prevention/contact_len.html

CDC-NIOSH – Contact Lens Use in a Chemical Environment: http://www.cdc.gov/niosh/docs/2005-139/

8.2 Hand protection

8.2.1 Selection of Gloves

Gloves are to be used to provide protection against chemical or biological hazards and exposure to extreme temperatures, abrasions or lacerations. Table 3 provides a general guideline to describe 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. See section 7.2.1.1	**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

Modified table taken from http://www.ccohs.ca/oshanswers/prevention/ppe/gloves.html, November 15, 2005

8.2.1.1 Chemical

No one 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 the different glove types varies significantly with the chemical in question. Consultation of the MSDS along with consideration of the usage will provide guidance in determining an appropriate glove. Table 4 provides some basic information about selecting gloves suitable for various chemical applications.

The following links provide more detailed information regarding the proper selection of a glove material based on the specific chemical(s) being handled.

Ansell Chemical Resistance Guide: http://www.ansellpro.com/download/Ansell_8thEditionChemicalResistanceGuide.pdf

http://www.ansellpro.com/specware/

Best Manufacturing Company's Chemrest: http://www.chemrest.com/

Table 4 – Characteristics, Advantages, Disadvantages and Uses of Selective 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. 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, many ketones	Oils, greases, aliphatic hydrocarbons, xylene, perchloroethylene, trichloroethane. 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 (Viton®)	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.

Modified table taken from: http://www.ecu.edu/cs-admin/oehs/ih/Glove-Selection-Chart.cfm , OCtober 24, 2007

8.2.2 Use and Care of Gloves

The following guidelines should be considered when using gloves:

- Inspect for damage prior to use. Any sign of deterioration, such as holes, tears or discoloration, should prompt immediate replacement of the gloves.
- Ensure appropriate fit and thickness to allow for the required tactile sensitivity.
- Ensure appropriate length so as to provide adequate protection of the arm.
- To remove: pull the gloves inside out to prevent exposure to any contaminants during removal.
- Remove gloves prior to touching computers or phones, opening doors or otherwise contacting items that would be expected to be free of contamination (either biological or chemical).
- Wash hands thoroughly after removal of gloves.
- Never reuse disposable gloves.
- Reusable gloves should be stored and maintained in such a way as to prevent exposure (e.g. in a Ziploc bag) and should be stored within the laboratory or work area. Manufacturer's instructions are to be followed as applicable.

8.3 Body Protection – Lab coats and aprons

Lab coats and long pants are to be worn whenever hazardous chemicals, radiological or biological substances are being used or handled. Shorts do not provide protection of the lower legs.

- Lab coats with snaps are preferred over lab coats with buttons to allow for quick removal of the clothing in the case of an emergency.
- Lab coats should have snaps fastened at all times while working in the lab.
- Lab coats are to be stored in the laboratory area to prevent biological or chemical contamination of non-lab areas.
- Lab coats are to be cleaned regularly and are to be laundered separately from all other clothing.

Aprons should be worn in addition to lab coats in situations where there is an elevated splash hazard or the risk of injury following a splash is high. Acid resistant aprons should be worn when working with large volumes (i.e. greater than four litres) of concentrated inorganic acids e.g. HCl, H_2SO_4. The use of aprons alone is discouraged as they provide inadequate protection of the arms.

Coveralls are generally not recommended in laboratory situations where flammable or corrosive liquids are being handled because of their potentially difficult removal should contamination occur.

8.4 Respiratory Protection

This section is to be used in conjunction with Policy 851.05.06. There are several types of respiratory protection that are appropriate for use in a laboratory setting depending on the work being performed. The use of a respirator should only be considered when permanent engineering controls are inadequate or non-functional e.g. emergency spill situations. Users must be registered in the University of Guelph Respirator program and appropriately trained and fitted prior to using a respirator. Fit-testing is required for all respirators and is provided by EHS. Contact the Occupational Hygienist at x54855 for more information.

Disposable dust masks are to be used when nuisance quantities of non-toxic dust are generated from the material(s) being used.

For situations where the air contains unacceptable or unknown concentrations of vapours or fine air-borne particles, a respirator may be required. These respirators are to be chosen and maintained with appropriate fit-testing and monitoring as required in Policy 851.05.06.

Respirators are to be stored such that they do not accumulate dust, i.e. in a drawer or box that allows sufficient ventilation to prevent growth of bacteria or mold. Respirators should be labelled with the name of the user. When being used, detection of an odour is confirmation that the respirator is either not providing a good fit or that the filter cartridges have expired.

8.5 Footwear

Closed-toed, closed-heeled shoes constructed of a resistant material (preferably leather) are required while in all laboratory areas. Steel-toed, chemical resistant safety shoes may be warranted in specific cases as determined by the laboratory supervisor. Sandals do not provide adequate protection and are not to be worn in any laboratory situation. High-heeled shoes are strongly discouraged as they increase the potential for tripping or falling.

8.6 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 must be worn in areas where the eight hour time weighted average noise level is greater than 85 dB. Noise monitoring can be performed by EHS personnel if required. Contact the Occupational Hygienist at x54855 for details. In cases where hearing protection is required, routine audiometric surveillance is conducted by OHW. Contact OHW at x54283 for more information and/or to initiate surveillance.

9. Emergency Procedures

9.1 Training/Laboratory Orientation

As part of orientation, it is the supervisor’s responsibility to ensure that all individuals are familiar with the use and locations of the following equipment *in all areas* in which they will be working:

- Fire extinguisher
- Eye wash station
- Safety shower
- Evacuation alarm
- Emergency routes and exits
- First aid kits
- Spill kits

Personnel responsible for or working within a laboratory are strongly encouraged to participate in fire extinguisher training. This training is offered through the University’s Fire Prevention office x52071 or https://www.uoguelph.ca/fire/services/request-training

9.2 Emergency Equipment

9.2.1 Fire Extinguishers

Discussed further in Section 10.2.

9.2.2 Emergency Showers and Eyewash Stations

Emergency (safety) showers and eyewash stations are the primary methods for decontamination after exposure to a hazardous substance. Treatment in the first 15-20 seconds following an exposure is critical to prevent serious injuries, particularly when working with a corrosive substance.

- Design and construction of eyewash stations and emergency showers are to meet the requirements in American National Standards Institute (ANSI) standard Z358.1-2009.
- Eyewash stations and emergency showers are to be readily available and easily accessible for each laboratory, i.e. less than 30 metres from a hazard and accessible within less than 10 seconds.
- Eyewash stations and emergency showers are to be unobstructed at all times.
- Emergency showers and eyewash stations should have additional signage to prominently display their location.

- Eyewash stations are to be activated at least once a week to verify operation and flush the pipes. Full inspections of eyewash stations and emergency showers are completed quarterly by Physical Resources.
- Any dysfunction of an emergency shower or eyewash station is to be reported to Physical Resources immediately at x53854.

GUIDELINES ARE BASED ON ANSI STANDARD Z358.1-2009.

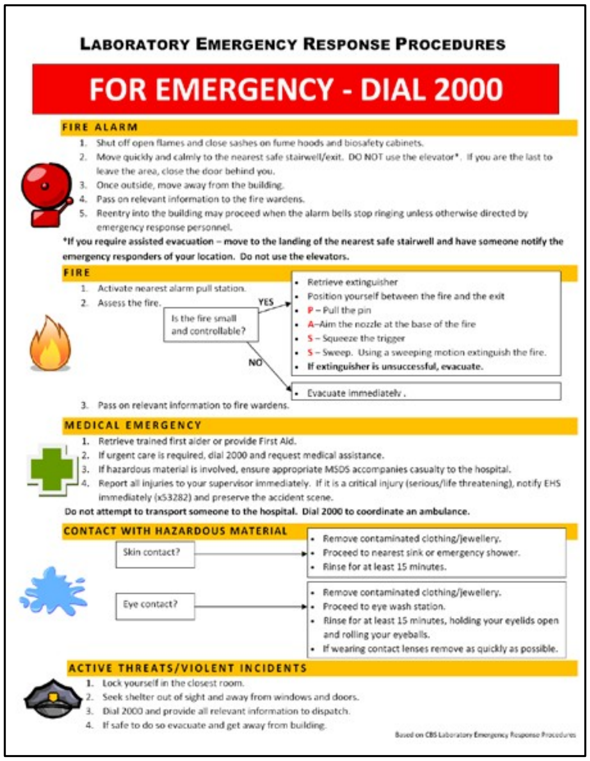
9.2.3 Spill Kits

Discussed further in Section 11.2.

9.3 Laboratory Emergency Procedures

Laboratory emergency response procedures are to be posted in each lab (Figure A). Posters for the Guelph Campus are available on the EHS website at: http://www.uoguelph.ca/ehs/programs/lab-safety. Note that posters applicable to the research stations and regional campuses are available by contacting the Lab Safety Officer, x56401

Figure A – Laboratory Emergency Response Procedures Poster



LABORATORY EMERGENCY RESPONSE PROCEDURES

FOR EMERGENCY - DIAL 2000

FIRE ALARM

1. Shut off open flames and close sashes on fume hoods and biosafety cabinets.
2. Move quickly and calmly to the nearest safe stairwell/exit. DO NOT use the elevator*. If you are the last to leave the area, close the door behind you.
3. Once outside, move away from the building.
4. Pass on relevant information to the fire wardens.
5. Reentry into the building may proceed when the alarm bells stop ringing unless otherwise directed by emergency response personnel.

***If you require assisted evacuation – move to the landing of the nearest safe stairwell and have someone notify the emergency responders of your location. Do not use the elevators.**

FIRE

1. Activate nearest alarm pull station.
2. Assess the fire.

Is the fire small and controllable?

YES

- Retrieve extinguisher
- Position yourself between the fire and the exit
- P – Pull the pin
- A–Aim the nozzle at the base of the fire
- S – Squeeze the trigger
- S – Sweep. Using a sweeping motion extinguish the fire.
- **If extinguisher is unsuccessful, evacuate.**

NO

- Evacuate immediately .

3. Pass on relevant information to fire wardens.

MEDICAL EMERGENCY

1. Retrieve trained first aider or provide First Aid.
2. If urgent care is required, dial 2000 and request medical assistance.
3. If hazardous material is involved, ensure appropriate MSDS accompanies casualty to the hospital.
4. Report all injuries to your supervisor immediately. If it is a critical injury (serious/life threatening), notify EHS immediately (x53282) and preserve the accident scene.

Do not attempt to transport someone to the hospital. Dial 2000 to coordinate an ambulance.

CONTACT WITH HAZARDOUS MATERIAL

Skin contact?

- Remove contaminated clothing/jewellery.
- Proceed to nearest sink or emergency shower.
- Rinse for at least 15 minutes.

Eye contact?

- Remove contaminated clothing/jewellery.
- Proceed to eye wash station.
- Rinse for at least 15 minutes, holding your eyelids open and rolling your eyeballs.
- If wearing contact lenses remove as quickly as possible.

ACTIVE THREATS/VIOLENT INCIDENTS

1. Lock yourself in the closest room.
2. Seek shelter out of sight and away from windows and doors.
3. Dial 2000 and provide all relevant information to dispatch.
4. If safe to do so evacuate and get away from building.

Based on CBS Laboratory Emergency Response Procedures

It is the laboratory supervisor's responsibility to consider and plan for possible laboratory emergency situations including those discussed below. These plans are to be documented and effectively communicated to all other lab personnel and are to provide specific information related to the emergency procedures of the laboratories with consideration of the particular materials, equipment, samples, procedures, personnel, etc. Laboratory supervisors are responsible for ensuring that there are appropriate evacuation procedures for persons with disabilities.

All staff and students are to participate in emergency drills as applicable and respond to all fire alarms by promptly following emergency procedures and evacuating the building. Elevators are not to be used during an evacuation. Buildings that have been evacuated may be re-entered once the alarm bells have stopped sounding unless otherwise directed by emergency response personnel.

9.3.1 Fires

Despite comprehensive preventative measures, fires may occur in the lab. In the case of fire:

- Call for emergency response. On the Guelph campus call x2000. At other locations including regional campuses, research stations, and Lab Services, AFL contact 911.
- Try to extinguish the fire if you can do so without putting yourself or others at undue risk.
    - 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.
    - **P**ull the pin.
    - **A**im the extinguisher nozzle or hose at the base of the flame.
    - **S**queeze the trigger.
    - **S**weep. Using a sweeping motion, extinguish the fire.
- Remember that portable extinguishers contain only enough material for 8-45 seconds depending on their size.
- If at any time, the fire becomes uncontrollable, activate the evacuation alarm and evacuate.
- Liaise with emergency responders to ensure that all relevant information is communicated.
- Seek medical attention if required.

If your clothing catches on fire:

- **Stop**.

- **Drop** to the floor.
- **Roll** to smother the flames.
- Get to the safety shower and rinse with copious amounts of water.
- Seek medical attention.

If another person’s clothing catches on fire:

- Assist them in the **Stop, Drop and Roll**.
- Assist in smothering the flames by covering them in a fire blanket, clothing or other appropriate item.

Fire safety is discussed in more detail in Section 10.

9.3.2 emical Contact

For skin contact:

- For a small, easily accessible area of the skin, e.g. the 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.

Follow up with medical professions should be initiated after any chemical contact:

For employees, contact OHW x 54283

For students, contact Student Health Services x 52131

9.3.3 ts and Needlestick Injuries

First aid treatment for minor scrapes, scratches, cuts, or needlestick injuries include the following:

- Apply gentle, direct pressure with a clean cloth or bandage to stop bleeding. If bleeding profusely, elevate injury above the level of the heart.
- Clean the wound with running water. Clean surrounding area with mild soap and running water, removing any dirt.
- Cover with a bandage or gauze square attached on all sides with adhesive tape. Avoid removing blood soaked bandages as this could damage a fresh clot – add additional bandages over top of the originals if necessary.
- Medical attention beyond first aid is required for:
    - Deep cuts that may require stitches.
    - Wounds caused by dirty or soiled objects to determine whether or not tetanus immunization is necessary.
    - Wounds caused by an object that has contacted blood or body fluids to determine if immunization or post-exposure prophylaxis is required.
    - Any injury that doesn't show signs of healing or you notice redness, swelling, warmth or drainage.

For more serious lacerations:

- Call for emergency response. At the Guelph campus call x2000. At other locations including regional campuses, research stations, and Lab Services, AFL contact 911.
- Attempt to stop the bleeding by elevating injured area above the level of the heart and applying direct pressure with a clean bandage or cloth.

Follow up with medical professions should be initiated after any needlestick injury:

For employees, contact OHW x 54283

For students, contact Student Health Services x 52131

9.3.4 Poisoning

Over-exposure to toxic substances can occur through inhalation, absorption, ingestion or injection. When assisting a victim of poisoning:

- Call for an ambulance for serious poisoning. At the Guelph campus call x2000. At other locations including regional campuses, research stations, and Lab Services, AFL contact 911.
- Ensure that the area is safe to enter before attempting to aid the victim.

- If safe to do so, move the victim away from the contaminated area and provide first aid as required.
- Contact the Poison Control Centre at 1-800-268-9017 for further instructions.
- Provide emergency medical personnel with the MSDS for the toxic substance.
- Always ensure that the victim receives medical attention, even if the exposure seems minor.

Follow up with medical professions should be initiated after any work-related chemical exposure:

For employees, contact OHW x 54283

For students, contact Student Health Services x 52131

9.3.5 Power failure

Laboratory supervisors should consider the consequences of prolonged loss of power to equipment, including refrigerators and freezers, in each laboratory. Any refrigerators or freezers containing flammable materials that require storage below room temperature must:

- Be connected to the back-up power supply.

Or

- Have an alternate refrigerator or freezer identified such that these materials can be transferred for continued safe storage.

Emergency procedures for such refrigerators/freezers should be posted on the refrigerator or freezer itself.

As well, in the event of a power failure, fume hood ventilation may be lost or reduced. See Section 9.3.11.

9.3.6 omestic Water Interruption

In the event of a domestic water interruption:

- Notify Physical Resources x53854 on the Guelph Campus (or Facilities personnel at other locations).
- Stop all work with or near hazardous materials until water is restored. Loss of water translates to inoperable emergency showers, eyewash stations and taps.

9.3.7 looding

Laboratory personnel should be aware of the location of the water shutoff for the lab. Laboratory personnel should ensure that electrical plugs, power bars etc. are not stored directly on the floor for protection against flooding.

- Stop source of flood if possible (e.g. turn off tap, shut off water supply to the lab etc.). If the source is unknown, contain flooding if possible.
- If the source of the flooding is unknown, the flood is uncontrollable, or significant damage is sustained: on the Guelph campus contact Physical Resources at x53854. Or x2000 if outside of normal business hours. Contact Facilities personnel at other locations
- If at any time you feel that your safety is being compromised, evacuate the lab and call for emergency response. At the Guelph campus call x2000. At other locations including regional campuses, research stations, and Lab Services, AFL contact 911.

9.3.8 emical Spills

It is important that you respond to spills only if you are trained in proper spill response, are comfortable and confident in the proper procedures for cleaning up the spill, can clean-up the spill safely and the spill is considered “incidental”.

See section 11 for detailed information on training, spill kits, spill classification, response and reporting requirements.

9.3.9 ological Spills

See the Biosafety Manual for appropriate response procedures.

9.3.10 Natural Gas Leak

Laboratory personnel should be aware of whether or not the lab and building are supplied with natural gas, and if so where shutoff(s) are located for the lab so that it can be turned off in the event of a leak. If a natural gas leak is suspected:

- Turn off the gas supply, if accessible.
- Evacuate the lab.
- Notify building occupants (may involve activating the evacuation alarm).
- Call for emergency response. At the Guelph campus call x2000. At other locations including regional campuses, research stations, and Lab Services, AFL contact 911.

9.3.11 Fume hood/Biosafety Cabinet Malfunction

In the event that fume hoods or biosafety cabinets become non-functional:

- Stop conducting any work requiring fume hood/biosafety cabinet ventilation.
- Ensure that all containers in the fume hood/biosafety cabinet are capped/sealed appropriately.
- Close sash.
- Notify other lab personnel of the malfunction.
- Contact Physical Resources at x 53854 on the Guelph campus. Contact Facilities personnel at other locations
- If an odour begins to accumulate, all personnel are to evacuate the lab until ventilation is restored.
- If a hazardous leak of chemical, vapours or biohazardous aerosols has resulted, activate the evacuation alarm and evacuate the building.

10. Fire Safety

Fire is a very plausible emergency situation that can occur in the laboratory. It is imperative that all reasonable precautions are taken to ensure that fires are prevented and that there is an understanding of the types of fires, how fires begin, how they are sustained and how they are controlled.

10.1 Fire Triangle

Fire can be described using the fire triangle:

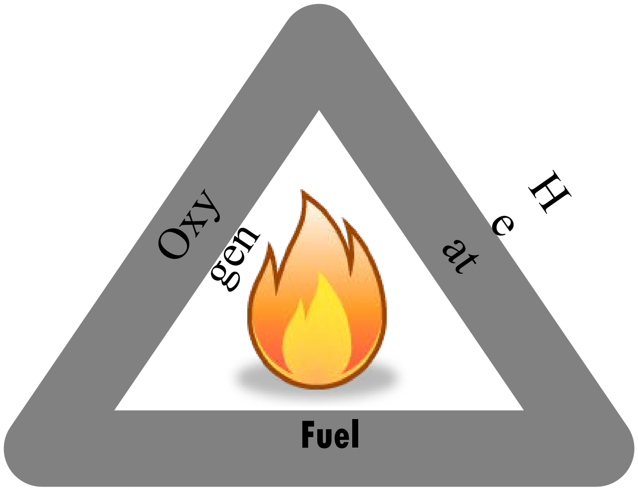


Figure B – Fire safety triangle

Fire cannot begin or be sustained without the three ingredients pictured above and therefore the removal of any one of these items leads to the basis of fire control.

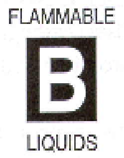
10.2 Classes of Fires and Extinguishers

There are four classifications of fire:

CLASS

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

CLASS



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

CLASS

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

CLASS

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

The type of fire extinguisher used to control the fire is dependent on the type of fire itself. Extinguishers are rated A, B, C, and D or combinations thereof. Each laboratory should have an ABC rated extinguisher. Laboratories using combustible metals may need to have a D rated extinguisher. Contact Fire Prevention at x52071 for further guidance.

Fire extinguishers should be conspicuously located near the exit(s) of the laboratories, be unobstructed and easily accessible at all times.

Any use of a fire extinguisher must immediately be reported to Fire Prevention at x52071 so that the extinguisher can be recharged or replaced.

10.3 Maintenance and Inspection of Fire Extinguishers

Fire extinguishers are to be maintained and inspected in accordance with Policy 851.02.03. Annual inspections of the fire extinguishers are coordinated through Physical Resources. Laboratory supervisors are responsible for ensuring that monthly checks are performed, however the responsibility for performing these monthly checks may vary depending on departmental policies. Monthly checks are to include ensuring that:

- the location of the fire extinguisher is conspicuous;
- the unit does not appear or feel empty;
- the locking pin is intact and sealed;
- the pressure is within the correct range, if a pressure gauge is present;
- there is no obvious physical damage, corrosion or leakage;
- the nozzle is not clogged; and
- the area around the fire extinguisher is clear of obstructions.

These monthly checks are to be documented on tags attached to the extinguishers.

Any deficiencies are to be reported to Fire Prevention at x52071.

11. Chemical Spill Prevention and Preparedness

Prevention of chemical spills is the most important aspect of a chemical spill response program. However laboratory personnel should be aware of spill clean-up procedures and be prepared to respond should a spill occur.

11.1 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 refreshed on at least an annual basis.

11.2 Spill Kits

Each laboratory using hazardous chemical materials shall 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 it is easily accessible at all times. Exact contents of a spill kit should be based on the hazardous properties of the materials present. Table 5 lists the recommended minimal requirements for spill kits.

Table 5 – 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 hydrofluoric acid o Bases o Flammable liquids o Formaldehyde o Organic peroxides
Plastic Scoop	• Polypropylene
Large Polyethylene Bags	• Strong composition • Leak proof • To be used as pail liners
Gloves	• Nitrile/Silver shield combination preferred • At least 2 pairs
Chemical Goggles	• Splash resistant • At least 2 pairs
20 L Plastic Pail with Lid	• Labelled as "SPILL KIT" • To contain spill equipment • When emptied to be used as disposal container for contaminated absorbents • Leak proof
Plastic Dust Pan and Broom	• Polypropylene bristles

Other items to you may want to add to your chemical spill kit, depending on the hazards present in the lab are:

- disposable Tyvek® suits;
- synthetic rubber aprons;
- duct tape;
- pH paper;
- hazardous waste tags; and
- specific neutralization mixtures.

When using acid or base neutralization mixtures, one should be prepared for heat generation and sputtering of the liquid.

Table 6 lists examples of specific neutralization mixtures.

Table 6 – Examples of Neutralization Mixtures Available for Spill Response

Neutralizer Type	Examples
Acid Neutralizers	• Sodium bicarbonate • Neutrasorb (colour change once neutralized) • Spill-X-A • Calcium carbonate (for hydrofluoric acid spills)
Caustic Neutralizers	• Citric acid powder • Neutracit-2 (colour change once neutralized) • Spill-X-C
Solvent Neutralizers (reduce vapours and increase flashpoint)	• Activated charcoal • Solusorb • Spill-X-S • Spilfyter vapour suppressor kit

If mercury or mercury compounds are present in the laboratory (including mercury in thermometers), a mercury spill kit shall be available. Table 7 lists the recommended contents for a mercury spill kit.

Table 7 – 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 monthly and documented, e.g. on an inspection tag. Inspections should include verifying contents and ensuring that supplies are unexpired and in good condition.

11.3 Spill Classification

Complex spills – Complex spills are those which involve chemicals or quantities of materials in excess of those outlined in Table 8, and require further assistance for clean-up:

Table 8 – Guidelines for the Classification of a Complex Spill

Material	**Quantity**
Air and water reactive materials	Any quantity
Flammable liquids	Greater than 4 L
Combustible liquids	Greater than 4 L
Non-flammable organic liquids	Greater than 4 L
Concentrated acids	Liquids greater than 1 L Solids greater than 1 kg
Concentrated bases and alkalis	Liquids greater than 1 L Solids greater than 1 kg
Mercury	Greater than 30 mL
Oxidizers	Liquids greater than 1 L Solids greater than 500 g
Highly toxic, highly malodorous materials (e.g. phenol, mercaptoethanol, hydrofluoric acid)	Liquids greater than 100 mL Solids greater than 50 g
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 Guide UG-RSOPROC-010 for proper procedures for radioactive spill response.

The above table provides guidelines for quantities only. Other considerations for classifying a spill as complex include whether or not respiratory protection is required and whether any 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 are unsure of the proper procedures.

Incidental Spills – These are minor spills not meeting the requirements of a complex spill that can be responded to by trained laboratory personnel.

11.4 Spill Response

Complex Spill Response:

- Evacuate the lab, close doors, restrict the area, and notify others in the area of the spill.
- Call x52000. University of Guelph dispatch will coordinate spill clean-up responses with EHS.
- If safe to do so:
    - Attend to injured or contaminated personnel.
    - If a flammable material is involved, turn off ignition sources (i.e. shut off power to area, turn off Bunsen burners, etc.)
    - Restrict or contain the flow of the spilled liquids.
- Activate emergency alarm if there is an immediate risk to the safety of other people in the building.
- Be available to provide technical information to emergency responders e.g. chemical identity, MSDS, identity of other equipment and hazardous materials in the lab.

If it is a complex mercury spill on the Guelph Campus, the fire prevention officers are to be notified. They will respond for clean-up with a mercury vacuum capable of effectively sucking up large mercury droplets. Note that regular vacuum cleaners shall not be used for clean-up of mercury in any situation as they will create harmful mercury vapours.

Incidental Spill Response:

- Attend to injured or contaminated personnel.
- If a flammable material is involved, turn off ignition sources.
- Restrict the area and notify others in the lab of the spill.
- Select and don all appropriate PPE. It is essential to properly protect yourself.
- Promptly attend to the spill according to Table 9. If unsure of the proper clean-up procedure, contact your supervisor for guidance. EHS is also available to provide guidance at x 53282.

Table 9 – Response Procedures for Incidental Chemical Spills

Material	Procedure
Acids, liquid	• If available, neutralize with sodium bicarbonate or commercially available acid neutralizer working from the outside in. • Using scoop, mix thoroughly to ensure neutralization. • pH paper can be used to test completeness of neutralization. Commercial neutralizers often change colour to indicate neutralization. • Add more neutralizer if necessary. • Proceed as per general liquid spill clean-up.

Caustics, liquid	• If available, neutralize with citric acid or commercially available caustic neutralizer, working from the outside in. • Using scoop, mix thoroughly to ensure neutralization. • pH paper can be used to test completeness of neutralization. Commercial neutralizers often change colour to indicate neutralization. • Add more neutralizer if necessary. • Proceed as per general liquid spill clean-up.
Solvents	• If available, suppress vapours with activated charcoal or commercially available solvent neutralizer working from the outside in. • Using scoop, mix thoroughly. • Proceed as per general liquid spill clean-up.
General liquids	• Encircle with universal chemical absorbent pads, socks or powder. • Cover the spill with universal chemical absorbent pads or powder. • Allow liquid to be absorbed. • Once absorbed, transfer to garbage bags using scoop and/or dust pan if necessary. • Label bag appropriately with hazardous waste disposal tag and complete hazardous waste disposal form.
Mercury	• Contain the spill. • If available, spray mercury suppression spray into immediate air space. • Push all mercury beads together. • Using the aspirator, transfer mercury beads to plastic disposal container. • Label disposal container appropriately with hazardous waste disposal tag and complete hazardous waste disposal form. • Cover spill area with mercury amalgamation powder. • Allow mercury amalgamation powder/mercury spill to solidify (form amalgam). • Use dust pan and broom or scoop to transfer amalgam into disposal container. • Decontaminate area with mercury decontamination liquid, wipes or sponges. • Transfer all wipes, sponges, gloves etc. used in clean-up to plastic bag, label with hazardous waste disposal tag and complete hazardous waste disposal form.
General solids	• If there is concern about harmful dust generation, encircle and cover the spill with universal chemical absorbent powder. • Transfer to garbage bags using scoop and/or broom and dust pan. • Label bag with hazardous waste disposal tag; complete hazardous waste disposal form.
Compressed Gas/Cryogenic Liquid Leaks	• Turn off cylinder valve. • If possible transfer cylinder to fume hood. • Check for leaks using a non-reactive detergent solution or commercial leak detection solution. If leak is obvious omit this step. • If leak continues, and gas is inert, evacuate lab and surrounding area and treat as a complex spill. If gas is toxic, flammable or corrosive, activate the emergency alarm, evacuate the building and treat as a complex spill. • N.B. Depending on the room size and the amount of gas, an oxygen deficient atmosphere may develop. Take particular care to ensure your safety.
Hydrofluoric Acid	• Ensure protective clothing including an appropriate respirator is worn and that the HF antidote is readily available. • Slowly apply solid calcium carbonate working from the outside in. • After the acid is absorbed, mix thoroughly with plastic scoop to ensure neutralization. • Use pH paper to test completeness of neutralization. • Add more neutralizer if necessary. • Proceed as per general liquid spill clean-up.

11.4.1 Mercury Spill Response

Responsibilities:

It is the responsibility of the laboratory personnel (lab supervisors, lab managers, undergraduate and graduate students, postdoctoral fellows and project students) to ensure that proper mercury spill response procedure and work practices are observed:

a) Have received and follow appropriate mercury spill response training specific to the laboratory environment. Training should be documented and refreshed on at least an annual basis
b) Have access to mercury related MSDS/SDS

Immediately alert area occupants and lab supervisor of the spill incident.

c) Have access to appropriate personal protective equipment (PPE)
d) Have access to sufficient quantities and types of appropriate spill control materials
e) Have read and understand this procedure

Mercury Spill cleanup Procedure

There are two types of mercury spills:

Incidental spill – spill of **less than 30 ml of mercury,** usually resulting from the breakage of a thermometer in a laboratory setting. This spill can be responded to by trained laboratory personnel

Complex spill – spill of **more than 30 ml of mercury** and/or where mercury has been spilled to a drain, to a heated surface, to a non-mobile porous surface (carpet), to an inaccessible area (floor cracks, beneath or inside of cabinets, etc.). Complex spills should be reported immediately to U of G Campus Police at x (5)2000. Interim measures should be taken to prevent unnecessary exposure (shut off oven or heating device if one is involved, vacate the spill area, close doors, secure the area, etc.).

Spill Response

Laboratory personnel shouldn't attempt to clean-up if they have not been trained in the proper mercury spill response or are in doubt of the proper procedures. In such a case call Campus Police at x(5)200 and they will attempt to contact EHS Department

- Immediately alert area occupants and lab supervisor of the spill incident
- Attend to any people who may be contaminated. Refer to mercury MSDS and follow first aid procedure
- Evacuate the area if spill is classified as complex. Call Campus Police x (5)2000. Placard the door to the laboratory with the following words, "Mercury Spill-Do Not Enter."
- Contain incidental spill and restrict admission to only those cleaning up the spill

- Access the Mercury Spill Kit (for recommended content refer to section 11 or purchase commercially available kits)
- Put on personal protective equipment: lab coat, safety goggles and a pair of nitrile gloves
- Review the mercury MSDS/SDS as required

Mercury Residue Clean-up:

Follow instruction from the commercial kit or do the following:

- Contain the spill
- Spray mercury suppression spray into immediate air space
- Push all mercury beads together and transfer into plastic disposal container using respirator
- Cover spill area with mercury amalgamation powder or sulfur powder. Allow for amalgamation process (the mixture will solidify or the applied sulfur to a mercury spill will turn from yellow to brown as it forms mercuric sulfide
- Transfer the amalgam or mercury sulfide into disposal container
- Decontaminate area with mercury decontamination liquid, wipes or sponges
- Cover the surface with mercury indicator powder if applicable and assess the presence of remaining mercury
- Transfer all wipes, sponges, gloves etc. into plastic bag and dispose of as hazardous waste
- Label disposal container with yellow hazardous waste tag signed “Mercury Spill Residue” and proceed with hazardous waste disposal procedure
- Wash hands, arms and face thoroughly

Additional Precautions:

Never use a regular vacuum to clean up mercury or to go over spill areas after they have been cleaned up
Be alert to “tracking.” It may be necessary to use disposable shoe covers if the spilled mercury has impacted a large area. Dispose of any contaminated cloths or footwear by placing them in a sealed plastic bag for disposal
Do not use a broom to sweep up the mercury. It can break the mercury into smaller beads, spreading them. Do not pour mercury down the drain. You may contaminate the plumbing and sewer system

Contact EHS for environmental monitoring and clean up services if airborne exposure is of concern because of unique circumstances or spill size.

12. Fume hoods and Biosafety Cabinets

Fume hoods and biosafety cabinets are critical pieces of laboratory equipment and, if used and maintained properly, are the most common and effective engineering controls in place to protect laboratory personnel against exposure to hazardous materials.

12.1 Chemical Fume hoods

All work involving hazardous chemicals should be performed within an appropriate chemical fume hood or ventilation system. Below is a diagram of a typical fume hood system.

Figure C – Diagram of typical fume hood system

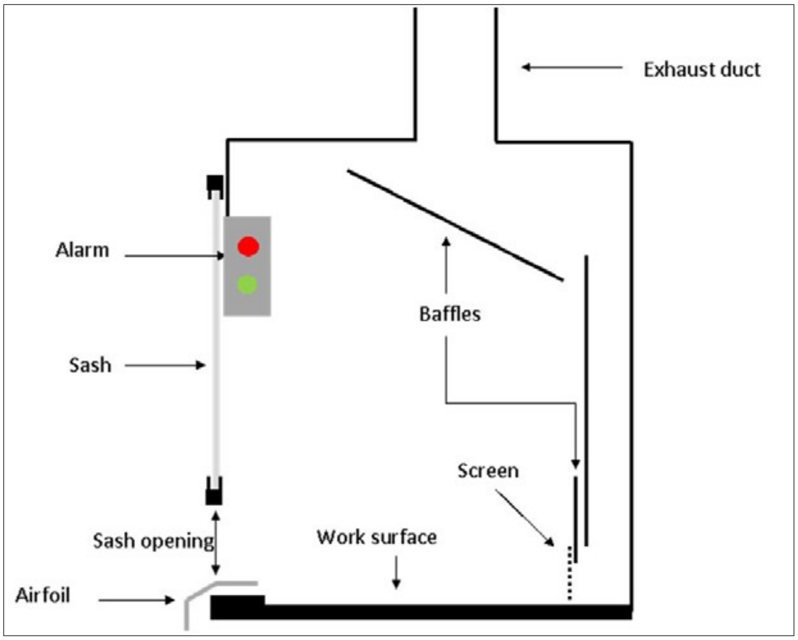


Table 10 provides a description of the types of chemical fume hoods/ventilation systems used throughout the University.

Table 10 – Use and Characteristics of Different Types of Laboratory Ventilation Systems

Type	Description	Purpose
Standard (Constant Volume)	Face velocity increases as the sash is lowered. Air flow directed to the outside through duct work.	Standard use
Bypass and Variable Volume systems (Constant velocity)	Face velocity remains constant as sash is lowered or raised. Air flow directed to the outside through duct work.	Standard use
Perchloric acid /Wash-down	Fume hood with wash-down system and constructed of materials resistant to reaction with perchloric acid. Either standard or bypass ventilation systems.	Use with perchloric acid only.
Self-contained	Air flow through filter (e.g. activated charcoal) and then recirculated into lab environment.	Suitable only for moderate work with substances with low toxicity/hazards. Filters must be chosen based on the chemicals to be used. The purchasing and use of these hoods is suitable in limited situations only.
Spot 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.

Digesting with or boiling of sulphuric acid or significant usage of nitrates requires either neutralization of the vapours prior to exhausting through the fume hood or engineered adjustments to the design of the exhaust system to ensure proper performance and longevity of the fume hood along with environmental regulatory compliance. Contact EHS at x56401 for more information.

It is recommended that for normal use, fume hoods have face velocities of 80-130 fpm with a sash opening of 45 cm 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. Face velocities (as a performance measure) and fume hood alarms are checked annually. On the Guelph campus this program is coordinated by EHS.

On the Guelph campus, Physical Resources is responsible for routine preventative maintenance of fume hood exhaust fans. This includes inspection of pulleys, belts, alignment, flexible connections, dampers and operation of the fan as well as greasing of fan and motor bearings as applicable. Parts are replaced as required. If a problem with fume hood ventilation is identified, on the Guelph campus contact Physical Resources at x53854. At all other locations contact Facilities personnel.

12.2 Biosafety Cabinets

Refer to the Laboratory Biosafety Guidelines for detailed information on types, use, operation and maintenance of biosafety cabinets.

Biosafety cabinets are designed to protect people and the environment from contamination by microorganisms as well as 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, biosafety cabinets should not be used for chemicals as they may have lower face velocities, recirculate the air within the cabinet leading to potential of vapour accumulation, and consist of filters that are not suitable for the collection of chemical vapours.

12.3 Proper Use of Fume hoods/Biosafety Cabinets

As mentioned, chemical fume hoods and biosafety cabinets are the primary source of protection against hazardous materials. In order for these critical pieces of equipment to be effective, the user is to:

- 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 fume hood/cabinet as this restricts the air flow. Flammable solvents/reagents are not to be stored in the fume hood/cabinet.
- Avoid blocking the baffle(s); place equipment upon legs if possible to maintain effective airflow.
- Work a minimum of 10 cm into the fume hood/cabinet.
- Never work in a fume hood/cabinet that is in alarm.
- Have an indication of the performance of the fume hood/cabinet, e.g. a continuous flow meter, alarm etc.
- Ensure that all waste, reagents, solvents and samples are sealed when not being used.
- Ensure that all permanent equipment is mounted appropriately.
- Ensure that all electrical connections are outside of the fume hood/cabinet
- Ensure that the fume hood/cabinet is kept clean, uncluttered and tidy.
- Ensure that sinks are protected from chemical spills, i.e. that in the event of a spill, it cannot go down the drain.
- **Always close the sash when not in use**.

Some ventilation systems on the Guelph campus are designed such that the exhaust will be reduced if sensors indicate that there is no use, i.e. the sash is closed, or after a specified time. While this is an important energy conserving initiative, it requires the participation of the fume hood users to be safe and successful. **Closing the fume hood sash is critical for this system to**

work. As well, it is critical that no one mistakenly works in a fume hood that has had its exhaust ventilation reduced.

13. Specific Chemical Hazards

All chemicals used in the laboratories at the University of Guelph should be used with the utmost caution according to good laboratory practices. There are certain chemicals or classes of chemicals, however that require specific handling precautions that are described briefly in the following sections. It is beyond the scope of this manual to address the hazards and precautions of all of the chemicals that may be found in the University's laboratories as well as delve into the details of the hazards of the chemicals mentioned. For further information regarding the toxicity, safe handling and use of specific chemicals, the appropriate MSDS or references such as the following should be consulted:

NIOSH Pocket Guide to Chemical Hazards, September 2007 Publication number 2005-149 (http://www.cdc.gov/niosh/npg/npg.htmL)

Sax's Dangerous Properties of Industrial Materials 11th ed., Richard Lewis. Published by John Wiley and Sons Inc.

Bretherick's Handbook of Reactive Chemical Hazards7th ed., Peter Urben. Published by Academic Press.

13.1 Flammables

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

- Ensure containers are grounded and bonded 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.

Laboratories that store, use or handle flammable or combustible liquids are to conform to section 4.12 of the Ontario Fire Code. See section 15.4 for more information.

Note that due to the highly flammable nature of diethyl ether, diethyl ether extractions are to be performed only in facilities with additional fire suppression systems and ventilation, as well as intrinsically safe wiring.

13.2 Oxidizers

Oxidizers are capable of igniting flammable and combustible material even in oxygen-deficient atmospheres as well as increasing 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.

13.2.1 Solids

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

- chlorates;
- perchlorates; (these are especially dangerous and their use should be avoided)
- nitrates;
- chromates; and
- permanganates.

13.2.2 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 its use is necessary, it must be done by personnel trained in specific handling procedures. Work involving heating of concentrated perchloric acid is to be performed in specialized, dedicated wash-down fume hoods (see section 12). 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
- Sulphuric acid

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

13.2.3 Use of Oxidizers

When using or storing oxidizers in the laboratory, the following precautions to take include the following:

- Keep away from flammable and combustible materials.
- Keep containers tightly closed unless otherwise indicated by the supplier.
- Store strong oxidizers in inert, unbreakable containers. The use of corks or rubber stoppers is not permitted.
- Mix and dilute according to the supplier's instructions.
- Dilute with water to reduce the reactivity of solutions.
- Wear appropriate personal protective equipment.
- Ensure that oxidizers are compatible with other oxidizers in the same storage area.
- Reaction vessels containing oxidizers shall not be heated with oil baths.

13.2.4 Peroxygen Compounds

These are chemically unstable compounds including peroxides, hydroperoxides, and peroxyesters that have a violently reactive oxygen. Some peroxygen compounds decompose slowly at room temperature, but rapidly at elevated temperatures. However, others decompose readily at room temperature and therefore must be refrigerated. Organic peroxides can violently explode when subjected to heat, friction, shock, spark, oxidizing and reducing agents or light. These compounds are very difficult to control in a fire due to their ability to generate their own oxygen upon combustion. Peroxygen compounds can seriously irritate the skin and eyes upon contact. Special consideration should be taken when using any compounds that have the capability of forming peroxides. The following are compound types that can be expected to form peroxides upon prolonged exposure to light or air:

- Ethers
- Aldehydes, ketones
- Compounds containing benzyllic, or allylic hydrogens
- Compounds with a vinyl or vinylidene group

The following is a partial list of compounds that can form peroxides:

Table 11 – Partial List of Chemicals that May Form Peroxides

Chemicals that form explosive levels of peroxides without concentration	
• Isopropyl ether • Butadiene • Chlorobutadiene • Potassium amide • Potassium metal	• Sodium amide • Tetrafluoroethylene • Divinyl acetylene • Vinylidene chloride
Chemicals that are a peroxide hazard on concentration	
• Acetal • Cumene • Cyclohexane • Cyclooctene • Cyclopentene • Diacetylene • Dicyclopentadiene • Diethylene glycol dimethyl ether (Diglyme) • Diethyl ether	• *p*-dioxane • Ethylene glycol dimethyl ether • Methyl acetylene • Methyl cyclopentane • Methyl i-butyl ketone • Tetrahydrofuran (THF) • Tetrahydronaphthalene (Tetralin) • Vinyl ethers

Modified table from Prudent Practices in the Laboratory, National Research Council, National Academies of the Press, 2011, Page 72.

13.2.4.1 Use, Handling and Storage of Peroxygen Compounds

Specific precautions to take when using, handling and storing peroxygen or peroxide-forming compounds include the following:

- Purchase and use only the minimum amount required.
- Purchase with peroxide inhibitors whenever possible
- Mark the receipt date on the container.
- Mark the date the container was opened on the container.
- Dilute solutions with inert solvents such as aliphatic hydrocarbons. Avoid the use of aromatic solvents, such as toluene, which can initiate the decomposition of some peroxides.
- Avoid preparing peroxide solutions with volatile solvents as losses of solvent due to evaporation can cause unwanted concentration of peroxides.
- Dispense quantities as required. Do not return unused materials to stock container.
- Do not use metal spatulas.
- Do not use glass containers with ground glass or metal lids. Use polyethylene containers with screw cap lids.
- Store and use away from heat, ignition sources and light.

- Store at the lowest temperature that is above the freezing point of the solution and that will not affect the solubility of solution. This will minimize the rate of decomposition of the peroxides.
- Dispose after one month of the container being opened or if unopened, by the expiry date.
- Treat any visible solids around the cap or in the container of peroxygen or peroxide-forming liquids with extreme caution as they could be explosive.
- Ensure that solutions are free of peroxides before concentration using the tests described below.
- If concentration is necessary, avoid evaporating to dryness.
- Use a shield when evaporating or distilling any peroxide-forming compounds.

13.2.4.2 Testing for Peroxides

Commercially available peroxide test strips can be purchased from laboratory supply companies. These allow a simple and quick qualitative determination of whether peroxides are present in a solution.

Alternatively the following colourimetric 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 should not be applied to solutions that may contain inorganic peroxides.

13.3 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.

13.3.1 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, hydrofluoric acid* etc.

- Strong bases (aqueous sodium hydroxide, potassium hydroxide, ammonia, etc.)
- Strong dehydrating agents (phosphorus pentoxide, calcium oxide, etc.)
- Strong oxidizing agents (peroxides, etc.)

*Hydrofluoric acid may be fatal through inhalation, absorption or ingestion and causes extensive, deep and painful burns. Avoid use if possible however if its use is unavoidable, personnel are to be specifically trained in its use and emergency response procedures. More information and use requirements are available at: http://www.uoguelph.ca/ehs/programs/lab-safety

13.3.2 Corrosive Solids

Inhalation of corrosive dusts presents a particular hazard as the point of contact and the tissue at risk, particularly the airways and lungs, is internal, creating an injury that may be difficult to treat and heal. Examples of corrosive solids are lithium oxide, sodium sulphide and phenol.

13.3.3 Corrosive Gases

Corrosive gases enter the body through inhalation as well as being readily absorbed through dissolution in skin and eye moisture. Typical examples are listed below:

- Ammonia
- Hydrogen chloride
- Hydrogen fluoride – inhalation, absorption or ingestion may be fatal. Causes extensive, deep and painful burns. Avoid use if possible, however if its use is unavoidable, personnel are to be specifically trained in its use and emergency response procedures. Formaldehyde
- Bromine
- Chlorine
- Phosgene
- Sulphur Dioxide

13.3.4 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 upon diluting or dissolving in water.
- Ensure that all work is completed in a chemical fume hood with adequate ventilation (see section 12).
- Personal protective equipment is to include:
    - labcoat;
    - goggles;
    - appropriate gloves; and
    - when working with volumes greater than 4 L, a synthetic rubber apron

13.4 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 the safe handling, use and storage of these sensitive chemicals.

13.4.1 Water reactives

The following situations may occur with water reactive chemicals upon 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 include:

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

13.4.2 Pyrophorics

Pyrophoric chemicals are those which ignite spontaneously upon 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, use in glove boxes, etc. More information and use requirements are available at the following link under
“Pyrophorics”: http://www.uoguelph.ca/ehs/programs/lab-safety

Examples of pyrophorics include:

- Alkyllithium compounds including *t*-butyllithium
- Boron
- Finely divided metals including calcium, cobalt, cadmium, iron, manganese, chromium, lead, nickel, titanium
- Dichloroborane
- Diborane
- Diethylzinc
- 2-Furaldehyde
- Grignard reagents
- Metal carbonyls e.g. lithium carbonyl, nickel carbonyl
- Metal hydrides, e.g. sodium hydride
- Non-metal hydrides e.g. diethyl arsine, diethyl phospine
- Phosphine
- Phosphorus

13.4.3 Organic Peroxides

See section 13.2.4

13.4.4 Explosives

Explosives are regulated by the Canadian Explosives Act and corresponding regulations along with the Ontario Fire Code. Specific requirements when handling explosives are described below:

- Working alone with explosive materials is prohibited
- Storage locations for explosive materials are to be placarded in accordance with the Explosives Act.
- Quantities of explosive materials are to be minimized with all additional material disposed of upon completion of the activity.
- Written safety instructions and emergency procedures are to be prepared and must include at least the following information:
    - location of storage and use areas
    - methods to control a fire emergency safely and efficiently
    - contact information

13.4.4.1 Picric Acid

Picric acid (2,4,6-trinitrophenol) is a reagent found in departments across campus, being used in microscopy and 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 are 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.

- Containers and lids for storage of picric acid or solutions of picric acid are not to 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.

If a container of dry picric acid is discovered, it is not to be touched and EHS is to be contacted at x56401 immediately to arrange for safe disposal.

13.5 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 fracturing 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:

- Control ice build-up.
- Use only approved low-pressure containers equipped with pressure-relief devices. Lunch box Thermos-style bottles are not acceptable.
- 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 are required in areas where the volume of gas could result in the displacement of oxygen to a level lower than what is tolerable by people, 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.
- To prevent thermal expansion of contents and rupture of the vessel, ensure containers are not filled to more than 80% of capacity.

- 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.

13.6 Designated Substances

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

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

The Designated substance regulation under the Occupational Health and Safety Act apply to employers and 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 be less than limits prescribed in the regulations. Generally, the regulation contains three key components:

Assessment – requires the employer to consider the level or likelihood of exposure of the worker to the substance.

Control program – required if the assessment discloses that a worker is likely to be exposed to the substance. This documented program is to include engineering controls, hygiene practices, work practices and facilities to ensure that the worker exposure to the substance is controlled.

Monitoring – requires air emissions monitoring and medical surveillance to determine actual exposure to the substance. Contact OHW x54283 regarding medical surveillance programs.

It is the responsibility of the laboratory supervisor to ensure that the letter and intent of the regulations are met. Contact EHS x56401 for more information. In addition to this regulation, additional information and standards have been added in the following sections.

13.6.1 Mercury

Elemental mercury, inorganic mercury salts and organic mercury compounds have the potential to cause serious acute or chronic toxic effects from the various routes of exposure.

- Containers are to be stored sealed with the cap/lid along with electrical tape, parafilm or an equivalent.
- All use and storage is to be in a well-ventilated area.
- Any skin or eye contact is to be rinsed with copious amounts of water and medical attention is to be sought immediately.

See section 11 for spill clean-up procedure.

13.6.2 Isocyanates

Various isocyanates have been determined to cause severe allergic reactions in certain individuals. Sensitization may also occur such that the allergic reaction becomes progressively worse with each exposure and occurs with exposures to very small amounts of the material. Reactions may include anaphylactic shock which can be fatal and hence requires immediate medical treatment. All laboratories, solutions or samples containing isocyanates should be clearly marked as containing such.

13.6.3 Benzene

Benzene is a highly flammable, carcinogenic solvent that has severe effects on the blood and blood-forming organs. All use of benzene should be performed in a fume hood. If practical, the use of benzene should be substituted with another appropriate solvent, such as toluene.

13.7 Nanomaterials

Nanomaterials are defined as particles with at least one dimension that is less than 100 nm. Nanomaterials have been shown to have unique physical and chemical properties when compared to the corresponding micro- or macro-scale compounds. In addition there also appears to be different mechanisms of toxicity and therefore different and potentially more severe health effects although these differences are currently widely unknown. As such use and handling of nanomaterials must be done with particular care and only after conducting a risk assessment to consider both the potential hazards and appropriate controls. Contact EHS for assistance in conducting a risk and/or exposure assessment. Examples of controls include:

- Identification of areas, equipment and containers that contain or are used with nanomaterials
- Embedding the nanomaterials in a solid matrix

- Working with the nanomaterials in solution within a chemical fume hood
- Working with solid, dry, dispersible nanoparticles in a fully contained system or conducting the work within a biosafety cabinet (HEPA filtered)
- Being diligent in housekeeping, wet wiping of potentially contaminated areas etc.
- Wearing appropriate personal protective equipment (gloves, lab coat, eye protection, respiratory protection etc.)

Please refer to the EHS website for more information.

13.8 Other Toxic Materials

Some other chemical materials warrant mentioning specifically because of their hazards and/or extensive usage. Their primary hazards are identified below:

- Ethidium bromide – known mutagen.
- Chloroform – relatively potent anaesthetic, suspected carcinogen.
- Cyanides/Nitriles – acutely toxic. If use is unavoidable, personnel are to be specifically trained in its use and emergency response procedures. Contact OHW x54283 for more information.
- Hydrogen sulphide – acutely toxic. Attacks the respiratory system. Highly flammable.
- Formalin/Formaldehyde – known carcinogen.

14. Compressed Gases

14.1 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 damage the cylinder valve resulting in a rapid release of gas that can transform a cylinder into an uncontrollable rocket or pinwheel and cause serious injury or damage. Poorly controlled release of compressed gas in the laboratory can burst reaction vessels, cause leaks in equipment and hoses or result in runaway chemical reactions. Compressed gases may also have flammable, oxidizing, dangerously reactive, corrosive or toxic properties. Inert gases such as nitrogen, argon, helium and neon can displace air, reducing oxygen levels in poorly ventilated or restricted areas and cause asphyxiation. See section 13.5 for information regarding cryogenic liquids.

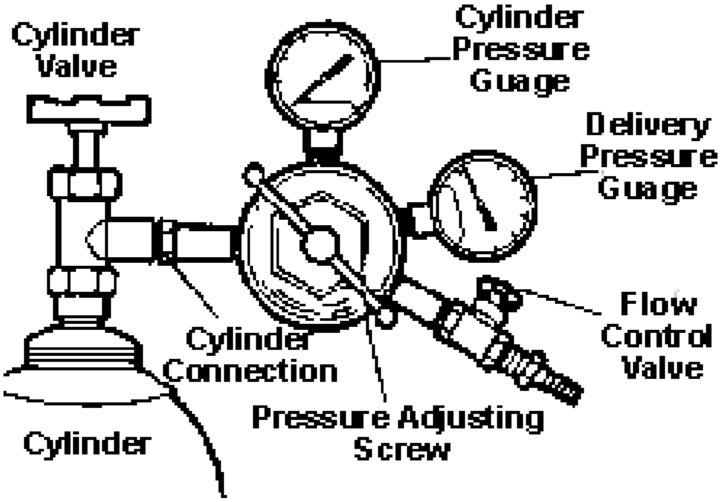
14.2 Handling and Transport of Gas Cylinders

The following points describe safe handling and transport guidelines for gas cylinders.

- Return unlabelled cylinders unopened to the supplier. Colour coding does not provide sufficient identification.
- Remove regulators and replace protective cap when cylinders are not in use or are being transported. Use a cylinder cart for transporting cylinders. Chain or strap cylinders to the cart.
- Avoid riding in an elevator with a gas cylinder. Elevators can be operated safely from the outside. Elevators may not have sufficient ventilation to maintain oxygen levels in the event of a gas leak.
- Ensure that propane tanks designed for outdoor use are not stored or used indoors.
- Label empty cylinders clearly with either “EMPTY” or “MT”.
- 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 expose cylinders to high temperature extremes.
- Do not force, lubricate or modify cylinder valves in any way.
- Ground cylinders containing flammable gases to prevent accumulation of electrostatic charge.
- Never expose skin or clothing to compressed gas flow as high velocity gas could penetrate the skin leading to 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.

14.3 Regulators

Figure D – Schematic diagram of compressed gas cylinder and regulator



http://www.safetyoffice.uwaterloo.ca/hse/cryogenics-compressed-gas/cg-use.html

- 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 cylinder being used. Compressed Gas Association (CGA) connector numbers are to be the same on the regulator and cylinder valve.
- Label all regulators appropriately and do not use interchangeably with different gases
- Do not rely upon the pressure gauge to indicate the maximum pressure ratings; check the regulator's specifications.
- Do not use adaptors or Teflon tape to attach regulators to gas cylinders. Regulator inlet connections are designed to fit the outlet connection of the cylinder valve for a particular gas. Gas tight connections are made using metal to metal seals which can be weakened or plugged through the use of Teflon tape.
- Use a properly sized wrench to attach a regulator to a cylinder. Adjustable wrenches are not to be used as they can damage the fittings.

14.4 Leaks

See information regarding compressed gas leaks in Table 8 and Table 9 in section 11.

14.5 Storage of Gas Cylinders

Storage of gas cylinders is regulated through the Ontario Fire Code Section 5.6. Proper storage room/locations for compressed gas cylinders are available throughout the University that meet the requirements of the Fire Code. Only cylinders that are in use are to be located in research or teaching labs.

- Storage areas are to be conspicuously labelled as such.
- All gas cylinders are to be securely supported in an upright position using suitable racks, straps, chains or stands. Cylinders should be secured at ~⅔ of their height. Cylinders with a height of less than 46 cm can be secured in specialized racks.
- All cylinders are to be protected from mechanical damage.
- Cylinders of flammable gases are to be segregated from oxidizing gases (e.g. oxygen stored separately from hydrogen).
- Cylinders are to be located in a dry location away from direct sunlight and heat sources.
- Cylinders are to be well removed from doors, aisles, stairs and elevators.

14.5.1 Segregation of Gas Cylinders

As with other chemicals, certain compressed gases are incompatible with each other. The following system describes the segregation required for compressed gases.

Figure E – Compressed gas segregation system

COMPRESSED GAS CYLINDER SEGREGATION AND STORAGE PLAN

	Flammable compressed gases	Oxidizing compressed gases	Non-flammable Toxic compressed gases	Non-flammable, Non-Toxic compressed gases
Flammable compressed gases	✓	✗	✗	✓
Oxidizing compressed gases	✗	✓	✓	✓
Non-flammable Toxic compressed gases	✗	✓	✓	✓
Non-flammable, Non-Toxic compressed gases	✓	✓	✓	✓

✓ – ok to be stored together ✗ – may not be stored together

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

15. Chemical Handling and Storage

Because of limited space, good housekeeping practices, waste disposal costs and the desire to minimize hazardous materials within the laboratories, it is essential to procure only what is needed in terms of reagents, solvents, etc. rather than buying in bulk. Storage of hazardous materials (including proper placarding of the storage locations) must be in accordance with all applicable legislation which may include the following:

- FIRE CODE - O. Reg. 388/97
- EXPLOSIVES ACT
- LIQUID FUELS - O. Reg. 217/01
- PROPANE STORAGE AND HANDLING - O. Reg. 211/01

15.1 EHS Chemical Inventory

All chemicals in every laboratory or storage area are to be entered into the EHS electronic chemical inventory system accessible on the EHS website Portal. This system is necessary to be able to efficiently communicate the contents of each lab or storage area to emergency first responders and to ensure that proper inventory control is achieved for each lab.

- Log-in ID's and passwords can be obtained by contacting EHS at x 53282 or at ehs@uoguelph.ca . Please provide your name, department, and the location of the materials to be inventoried (building and room number)
- Training is provided by EHS. Call x 53282 for details.
- Upon receipt of a new chemical, enter information into the inventory applicable to the laboratory.
- Update inventory as a chemical is depleted or disposed.
- Audit inventory on an annual basis to ensure that it is up to date.

15.2 General Transport Practices

- Use a cart when transporting several containers or containers that are large, awkward or heavy. Carts should either have high edges for containment or chemicals should be in secondary containers.
- Carry glass containers in bottle carriers or another suitable, leak resistant, robust secondary container.

- Transport off-site requires compliance with federal Transportation of Dangerous Goods regulations. Refer to Safety policy 851.08.10 or contact EHS x 54270 for more details.

15.3 General Storage Practices

- Ensure that storage shelves are sturdy and secured to the wall or floor.
- Ensure that storage shelves have anti-roll lips or that other appropriate measures are taken to ensure chemicals cannot easily fall off shelves.
- Store large containers on lower shelves.
- Avoid storage above eye level.
- Window sills, heaters and ledges are not to 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. Containers stored on the floor can be easily knocked over spilling contents.
- 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.
    - Outside of containers are kept free of spills and stains.
    - Containers are properly labelled.

15.4 Storage of Flammables and Combustibles

Flammable liquid – a liquid having a flash point below 37.8°C and having a vapour pressure not more than 275.8 kPa (absolute) at 37.8°C as determined by ASTM D323, "Vapour Pressure Petroleum Products (Reid Method)".

Combustible liquid – any liquid having a flash point at or above 37.8°C and below 93.3°C

Storage of flammable and combustible liquids in the laboratory is regulated by section four of the Ontario Fire Code. Maximum quantities listed below are for single labs (i.e. 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** are flammable liquids, as per Ontario Fire Code)

- Ensure that all additional flammable material (up to a total of 500 L of which not more than **235 L** of flammable liquids) is stored in approved flammable storage cabinets.
- Ensure that flammable materials requiring storage conditions at refrigerated temperatures are stored in refrigerators/freezers designed and certified for this purpose. **Household refrigerators are never to 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 which must be less than 25 L.

15.4.1 Storage Rooms for Flammable and Combustible Liquids

There are several designated flammable storage rooms at the University. Flammable storage rooms are to meet the following requirements:

- not be located in the basement of a building;
- separated from the remainder of the building with partitions having a minimum one-hour fire resistance rating and self-closing doors, hinged to swing outward;
- have no openings communicating directly with the public portions of the building;
- be equipped with a drain connected to a dry sump or holding tank;
- have liquid-tight seals between interior walls and floor and a liquid tight ramped sill at any door which is not an exterior door;
- have aisles of no less than 1 m;
- have a suitable portable fire extinguisher;
- have suitable spill clean-up materials;
- have appropriate ventilation:
- natural or continuous mechanical ventilation if no vapours can escape into the room;
- continuous mechanical ventilation if flammable vapours may be released into the room (Refer to the Ontario Fire Code for specific requirements for mechanical ventilation).

The maximum quantity of flammable and combustible liquids permitted in flammable storage rooms is 1500 L.

15.4.2 Approved Flammable Storage Cabinets

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

- Conform to ULC-C1275, “Storage Cabinets for Flammable Liquid Containers”;
- Conform to ULI 1275, “Flammable Liquid Storage Cabinets”;
- Be Factory Mutual Research Approved; **or**
- Be listed as meeting NFPA 30.

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

15.5 Chemical Segregation

It is critical that chemicals are stored according to a predetermined storage system to ensure that incompatible chemicals are not stored in close proximity to each other. Storage systems that account for necessary segregation are acceptable provided that they are clearly documented and understood by lab personnel. It is suggested that solvents/reagents etc. be labelled according to the storage system used to allow for continuous, easy and proper storage. A representative chemical segregation system that has been adopted by the University is described on the following pages.

Figure F – 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								
Explosives	×	✓	×	×	×	×	×	×
Flammables (solids & liquids)	×	×	✓	×	×	✓	✓	× Secondary
Oxidizers (solids & liquids)	×	× ×	×	✓	×	×		containment required
Corrosive Acids (solids & liquids)	×	×	×	×	✓	×	×	< 2 M acidic solutions
Corrosive Bases (solids & liquids) Non-flammable	×	×	✓	×	×	✓	Secondary containment required	< 2 M caustic solutions
solvents & regulated chemicals	×	× ×	✓	×		Secondary containment required	✓	✓

Secondary

Low-hazard solids & liquids	×	× ×		containment required	< 2 M acidic solutions	< 2 M caustic solutions	✓	✓

✓ – ok to be stored together ✘ – 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, potassium cyanide, 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, acetic acid
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 (see MSDS for details).	Examples: sodium dichromate, potassium permangenate, sodium periodate, sodium hypochlorite, benzoyl peroxide
Corrosive Acids (solids & liquids)	Store within dedicated acid cabinet. Use secondary containers particularly for hazardous acids such as hydrofluoric acid. Separate inorganic and organic acids. Aqueous solutions < 2 M and weak, non-corrosive acids are exempt.	Examples: sulphuric acid, hydrochloric 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 are to be stored based on the first suitable grouping listed above

15.6 Partial List of Incompatible Chemicals

The following list is not complete and is intended for use as a guide only. Refer to the appropriate MSDS for incompatibilities of chemicals not found in the following table.

Table 12 – 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

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
Tellurides	Reducing agents

15.7 Storage of Gas Cylinders

See Section 14.5.

15.8 Containment

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

- Primary storage containers should be of a composition such that they are able to maintain their structural integrity, under normal storage and use, throughout the lifespan of the material they are holding.
- Purchase materials in safety-coated glass bottles if available. These are glass bottles that are covered in a thin plastic coating that is slip and impact resistant. These bottles are designed to contain liquid in the event that the glass is broken.
- *Secondary containment should be used in all storage locations*. This is containment in addition to the primary container to prevent release of material to the environment in the event that the primary container fails. Over-packs, spill trays etc. are examples of secondary containment.

16. 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 fume hood as methods of disposal. Not only is this practice a contravention to the legislation, but it can harm the environment, lead to dangerous reactions, create immediate and future hazards for lab and trades personnel, as well as damage the drainage system. The sign shown in Figure G is to be posted near all sinks in all University labs:

Figure G – Sewage disposal of hazardous waste warning sign

WARNING

It is dangerous and unlawful to dispose of flammable, toxic, corrosive, oily, or other hazardous waste down drains.

FOR DISPOSAL, CONTACT
ENVIRONMENTAL HEALTH AND SAFETY
PHONE 53282

Detailed information regarding acceptable discharges to sanitary and storm sewers can be found in the City of Guelph's Sewer Use by-law. A summary of unacceptable discharges can be found in Table 12.

Table 13 – Summary of Unacceptable Discharges to Sanitary Sewers

Matter of any type, temperature or in any quantity which may:

- be or become a health and safety hazard to any person, animal, property or vegetation;
- cause sewage effluent, sludge or compost to contravene Provincial regulations;
- be harmful to the sewage works; or
- interfere with the proper operation of sewage works or treatment.

Solid or viscous substances in such quantity or size that may cause obstruction to flow of sewer including but not limited to ashes, bones, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, plastics, wood, unground garbage, animal guts or tissues, paunch manure, whole blood or the product of any garbage grinder.

Sewage or uncontaminated water with a temperature greater than 65°C.

Sewage with pH less than 5.5 or greater than 9.5.

Sewage containing the following in any amounts:

- dyes or colouring materials which may discolour the sewage works effluent;
- items that may cause offensive odours including hydrogen sulphide, carbon disulphide, reduced sulphur compounds, amines or ammonia;
- water from an unapproved source separate from the water distribution system of the City;
- storm water;
- water immiscible liquids;
- fuel;
- PCBs;
- pesticides;
- severely toxic material;
- waste radioactive material (except where discharge is being done in accordance with a licence from the Canadian Nuclear Safety Commission);
- hauled sewage;
- waste disposal site leachate; and
- hazardous wastes (including acute hazardous waste chemicals, hazardous industrial wastes, hazardous waste chemicals, ignitable wastes, pathological wastes, PCB wastes, reactive wastes)

Sewage containing any of the following in excess of the indicated concentration:

Solvent extractable matter of mineral or synthetic origin	15 mg/L
Biological oxygen demand	300 mg/L
Suspended solids	350 mg/L
Organic nitrogen, solvent extractable matter of animal or vegetable origin	100 mg/L
Chlorides, Sulphates (SO_4)	1500 mg/L
Aluminum, Iron	50 mg/L
Fluorides, Phosphorus	10 mg/L
Antimony, Bismuth, Chromium, Cobalt, Lead, Mangenese, Molybdenum, Selenium, Silver, Tin, Titanium,Vanadium	5 mg/L
Copper, Nickel, Zinc	3 mg/L
Cyanide	2 mg/L
Arsenic, Cadmium, phenolic compounds	1 mg/L
Mercury	0.1 mg/L

Note that dilution is not an acceptable means of meeting concentration requirements.

Guelph Sewer Use By-law (1996)-15202 (and amendments)

Hazardous waste disposal is managed through the EHS department. Hazardous waste is not to be transported to the Guelph campus from offsite as the campus is not an approved waste transfer site or receiver. Hazardous waste generated at regional campuses and research stations must be transported by a hazardous waste contractor directly from these locations.

Hazardous waste disposal fees are considerable; however generally there is no cost to the labs or departments. Below are exceptions where the laboratory supervisor or department will be charged back for costs incurred from hazardous waste disposal.

- The waste generated is from a lab/department that has a cost recovery program (i.e. waste generated from services for which the lab or department is being paid to provide)
- Waste for disposal exceeds the amounts that would be reasonably expected to accumulate over a two-week period. Laboratory supervisors are responsible for ensuring that waste and outdated chemical inventory is efficiently managed. Waste disposal costs resulting from lab “clean-ups” will be charged back to the generator.
- Disposal of atypical wastes, e.g. explosives (such as dry picric acid), PCBs, compressed gases, etc.

Fees related to disposal of hazardous waste generated by regional colleges and research stations are the responsibility of the corresponding college or research station.

16.1 Minimization of Hazardous Waste

As an environmentally responsible scientist, it is important to minimize all waste generated. The following points should aid in waste minimization efforts.

- Buy only what you need.
- Miniaturize (scale down) 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 it can be accomplished efficiently, effectively and safely.

16.2 Packaging and Labelling Requirements

The waste generator is responsible for providing appropriate waste containers as well as ensuring that all hazardous waste is packaged and labelled appropriately. The safety of the hazardous waste contractors depends on the waste containers maintaining their integrity, and the waste being accurately identified. The following are items for consideration:

- Incompatible materials are not to be combined in a single waste container.
- Chemical liquid waste containers are 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 are not to be stored in glass containers; corrosives are not to be stored in metal containers).
- Containers are to be in good condition.
- Wastes are to be identified appropriately (e.g. biohazard bags are not to be used for chemical wastes if no biohazard exists).
- Non-hazardous wastes are to be segregated from hazardous wastes to avoid unnecessary expenses.
- Hazardous waste is to be disposed of regularly, i.e. not accumulated.
- Hazardous waste is to be clearly labelled with the identity of the waste as well as the waste generator. This will be accomplished by carefully completing the hazardous waste tag (shown in section 16.3).
- If reusing bottles, ensure that there is only one identifier on the bottle.

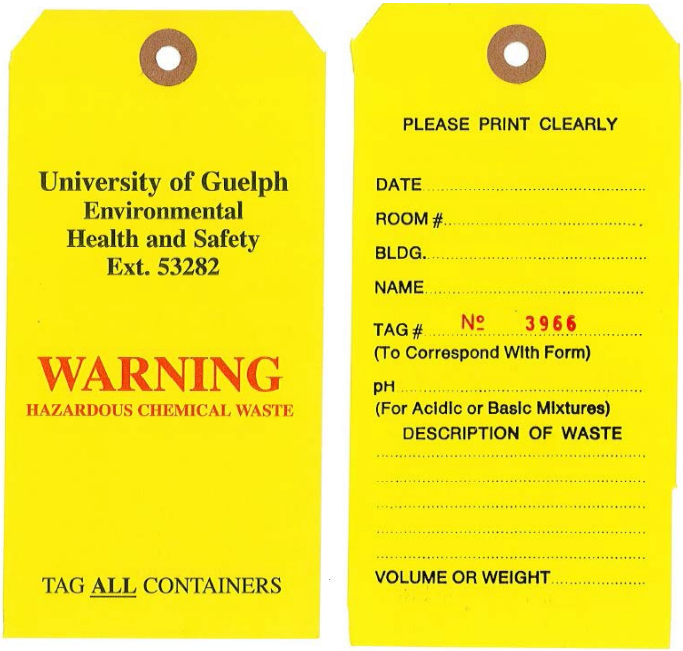
16.3 Chemical Waste

Hazardous chemical waste is picked up regularly by a hazardous waste contractor. Note that chemical containers and consumer products such as cleaning solvents, paints, paint thinners, oils and pesticides are to be disposed of as hazardous waste. All unused controlled drugs are to be returned to the University Pharmacist. The following procedures apply to the Guelph campus and Laboratory Services, AFL

If you have waste for disposal:

- Complete a hazardous waste disposal tag and attach to waste containers. See sample tag in Figure H. Tags are available from EHS.

Figure H – Hazardous waste disposal tag



University of Guelph
Environmental
Health and Safety
Ext. 53282

WARNING
HAZARDOUS CHEMICAL WASTE

TAG **ALL** CONTAINERS

PLEASE PRINT CLEARLY

DATE ……………………………
ROOM # ……………………………
BLDG. ……………………………
NAME ……………………………
TAG # № 3966
(To Correspond With Form)
pH ……………………………
(For Acidic or Basic Mixtures)
DESCRIPTION OF WASTE
……………………………
……………………………
……………………………
……………………………
……………………………
VOLUME OR WEIGHT ……………………………

- Complete “Sharps and Waste/Surplus Chemical Disposal” form either electronically or by hardcopy. The following information is required:
    - contact name, phone number/email, signature;
    - building number, room number, waste location;
    - chemical composition (No abbreviations. Abbreviations may be meaningless to those transferring waste, hence full chemical names are required.);
    - quantity, container description;
    - tag number; and
    - hazards, physical state, pH if required.
- Form available at http://www.uoguelph.ca/ehs/sites/uoguelph.ca.ehs/files/waste%20request%20form.pdf

- Submit form to EHS by interdepartmental mail, fax (519-824-0364), email ehs@uoguelph.ca) or in person to the main EHS office.
- Waste will be removed by the waste contractor through at least weekly, scheduled pick-ups. Regular pick-up days will be posted on the EHS website along with any cancellations or changes to the schedule.
- In the event of a problem (incomplete information, no tag, improper/defective packaging, inaccessible location, etc.), the waste will be rejected for pick-up and the contact person will be notified.
- Suitable waste containers (e.g. safety cans less than 25 L, nalgene carboys, etc.) will be returned to the generator.

16.3.1 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 appropriately identify or categorize the "unknown". Figure I provides a flowchart to assist in waste categorization.

If professional assistance is required to identify or categorize "unknowns", the resulting charges will be the responsibility of the waste generator.

16.3.2 Explosive Waste

Explosive waste will not be picked up during the regular, scheduled hazardous waste removal. To make arrangements for the disposal of explosives, contact EHS at x56401.

16.4 Biohazardous Waste

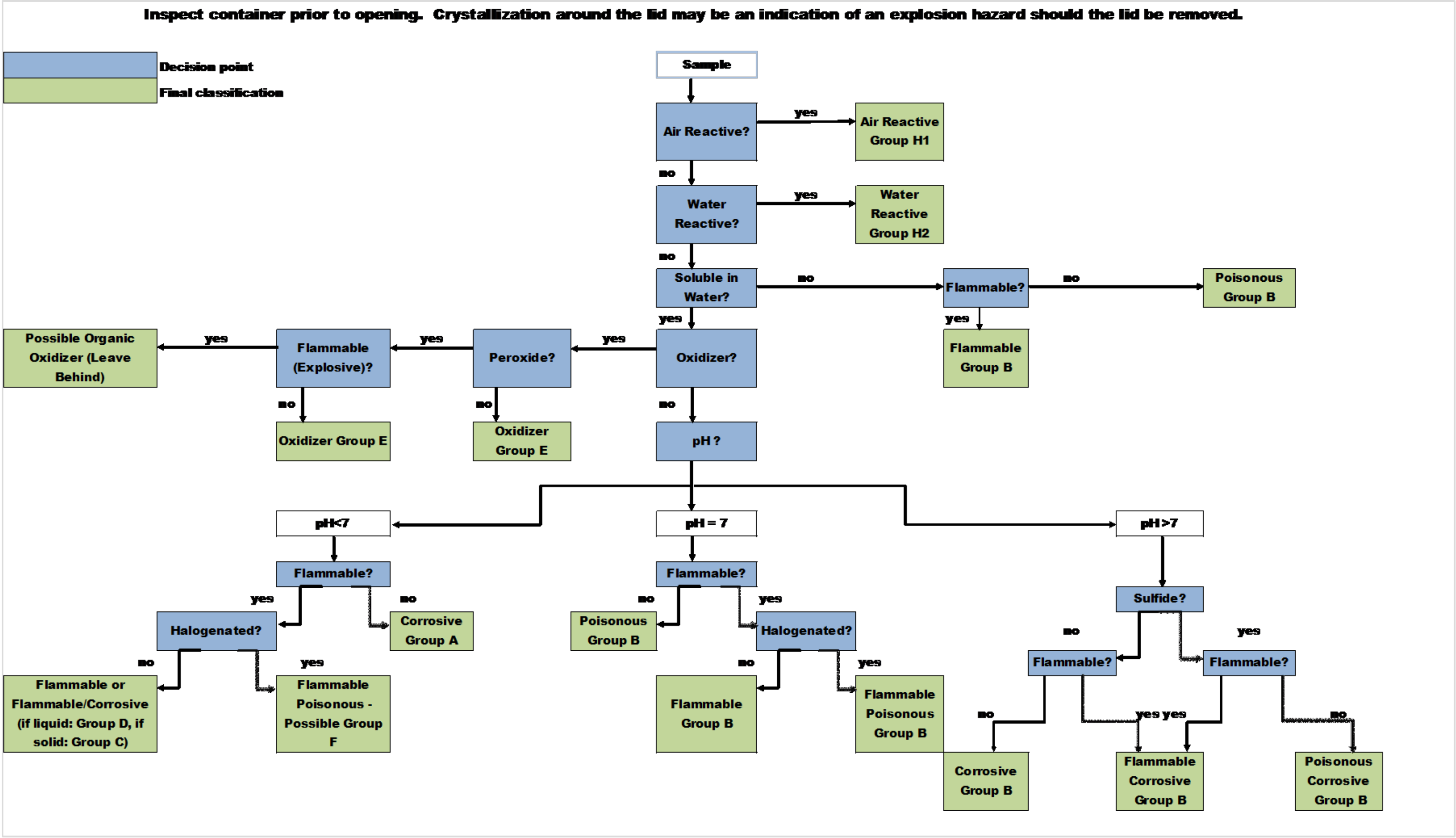
See Biosafety manual for details.

16.5 Radioactive Waste

See Radiation Guide US-RSOG-101-2004 revision 2 or later for details.

- Complete radioactive hazardous waste disposal tag and attach to waste containers.
- Complete "Request for Radioactive Waste Disposal" form which includes the following information:
    - contact name, phone number/email, signature, project number;
    - building number, room number, waste location;
    - radionuclide, scheduled quantity, total activity, activity concentration;
    - chemical composition (no abbreviations permitted);
    - quantity, container description;
    - tag number; and
    - hazards, physical state, pH if required.
- Form available at http://www.uoguelph.ca/ehs/sites/uoguelph.ca.ehs/files/radioactive-waste-disposal-aug509.pdf.
- Submit form to EHS by interdepartmental mail, fax (519-824-0364), email (ehs@uoguelph.ca) or in person to the EHS office.
- Waste will be removed from the lab by the waste contractor via at least weekly, scheduled pick-ups. Regular pick-up days will be posted on the EHS website along with any cancellations or changes to the schedule.
- In the event of a problem (e.g. incomplete information, no tag, improper/defective packaging, inaccessible location etc.), the waste will be rejected for pick-up and the contact person will be made aware of the problem via a "refusal ticket".

Figure I – Unknown waste categorization flow diagram



Inspect container prior to opening. Crystallization around the lid may be an indication of an explosion hazard should the lid be removed.

Property	**Description of Test***
Water reactivity/Water solubility	Add a small a quantity of unknown to a few milliliters of water. Observe any changes e.g. heat, gas formation, flames. Also observe whether the unknown is soluble in water and if insoluble if it is more or less dense than water.
pH	Determine the approximate pH using multirange pH paper.
Flammability	Place a small sample of the unknown in an aluminum test tray (i.e. <5ml). Apply an ignition source for up to 1 second. If it burns, it is flammable/combustible.
Presence of oxidizer	Use commercially available KI/starch test strips. Strip will turn blue in the presence of free iodide indicating the presence of oxidizer
Presence of peroxide	Use commercially available test strips. Follow manufacturer's directions.
Presence of sulphide	Use commercially available test strips. Follow manufacturer's directions.
Presence of halogen	Heat a copper loop to redness in a flame. Cool in distilled or deionized water. Dip into unknown. A green colour around the wire in the flame indicates the presence of halogen.

*Adapted from Prudent Practices in the Laboratory – Handling and Management of Chemical Hazards, 2011, National Research Council, Published by the National Academies Press.

16.6 Sharps Waste

Sharps are to be separated from regular waste streams to prevent unnecessary needlestick injuries and/or lacerations.

16.6.1 Broken laboratory glassware

Clean broken glassware including Pasteur pipettes, and broken laboratory glassware, is to be separated into an appropriately marked glass waste container. These containers are available from Physical Resources and consist of 5 gallon, white plastic pails, lined with a heavy-duty yellow garbage bag. Contact Physical Resources x58129 to request disposal containers. Custodial Services will remove glass waste once the containers are full.

Contaminated broken glassware is to be treated like sharps defined in section 16.6.2.

16.6.2 Syringes, needles, scalpels and blades

- Dispose in standard "Sharps" containers.

- When container is full, autoclave according to CCME guidelines[1] for biomedical waste (i.e. 120°C at 105 kPa for more than 60 minutes). If autoclaving is not possible, the container will be transferred to a biohazardous waste pick-up site. Contact EHS x 56401 for details.
- Complete hazardous waste disposal tag (Figure H) and attach it to the container.
- Complete "Sharps and Waste/Surplus Chemical Disposal" form and submit to EHS as with chemical waste.

16.7 Batteries

Batteries are to be disposed of as follows:

- Collect in a suitable container sturdy enough to handle the weight of the batteries.
- Complete hazardous waste disposal tag (Figure H) and attach to container.
- Complete "Sharps and Waste/Surplus Chemical Disposal" form and submit to EHS as with chemical waste.

Batteries may also be dropped off at the Physical Resources stockroom for subsequent pick up by the hazardous waste contractor.

17. Laboratory Equipment and Procedures

Many pieces of laboratory equipment can be hazardous if not used and maintained appropriately. Personnel should be trained on laboratory equipment prior to using the equipment. General precautions for a selection of apparatus are provided in the following sections. Specific operational instructions provided in manufacturer's instruction manuals and standard operating procedures are to be followed. These manuals/procedures should be located with the equipment or be otherwise easily accessible. Maintenance of or repairs to any laboratory equipment should only be performed by competent personnel trained and qualified to perform such work. Safety devices on laboratory equipment are never to be disabled.

17.1 Acid/Base Baths

Acid and base baths, often used to clean glassware are very corrosive, with the potential to cause significant injury to the personnel using them. Consideration should be given to substituting an

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[1] Code of Practice for the Management of Biomedical Waste in Canada, Canadian Council of Environment Ministers (CCME), 1990

acid/base bath with a bath prepared with a laboratory grade detergent. Chromic acid cleaning baths are not permitted without prior consultation with EHS.

- When preparing or handling acid or base baths, ensure that personal protective equipment includes a synthetic rubber apron, safety goggles, a face shield and long synthetic rubber gloves.
- Prepare the bath in a fume hood by first adding cold water, to which a measured amount of acid or base is slowly added.
- Take particular care to prevent splashing during the loading or unloading of the bath.
- When removing items from the bath, empty any residual liquid back into the bath and rinse thoroughly with water.
- Dispose of the spent bath in accordance with hazardous waste disposal procedures.

17.2 Alcohol Burners

Alcohol burners are gradually replacing the Bunsen burner in the laboratory. Using fuels such as methanol, ethanol or isopropanol, an open flame is generated for use in techniques such as flaming of microbiological loops.

- Fill the burner in a fume hood taking care not to spill or overfill.
- Transfer the burner to the location where it is to be used, away from flammable and combustible material.
- Never light a burner with another burner.
- Never refill a lit burner.
- Take care not to come in contact with the invisible flame.
- Ensure that long hair, loose clothing and jewellery are secured.

17.3 Atomic Absorption Spectrometers

Sample preparation for atomic absorption (AA) procedures often require handling of flammable, toxic and corrosive products. Familiarize yourself with the hazardous properties of these materials using the MSDS 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 recommendations when carrying out atomic absorption analysis are:

- Wear safety glasses for protection against impact.
- Inspect the integrity of the burner, drain and gas systems before use.
- Inspect the drain system regularly; empty the drain bottle frequently when running organic solvents.
- Allow the burner head to cool to room temperature before handling.
- Never leave the flame unattended. A fire extinguisher should be located nearby.

- Avoid viewing the flame or furnace during atomization unless wearing protective eyewear.
- Hollow cathode lamps are under negative pressure and should be handled with care and properly disposed of as hazardous waste to minimize implosion risks.
- Ensure gas delivery systems incorporate flash arrestors in the gas lines.

17.4 Autoclaves

Autoclaves present potential burn and explosion hazards and need to be used with the utmost care.

- Autoclaves must have a certificate of inspection prior to use and are inspected annually thereafter. Inspections are coordinated by the Insurance Manager, Financial Services and must be completed by a qualified inspector.
- The inspection certificate is to be posted in a conspicuous location near the autoclave itself.
- Autoclaves are to be serviced on at least a quarterly basis on a preventative maintenance contract. Service visits are to be documented (e.g. on a tag or in an equipment logbook.)
- Inspections and tests are to be performed by trained, qualified personnel.
- Autoclaves are to 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:
  - 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 are not to be autoclaved.
- Glassware is to be of borosilicate composition and checked for inspected for cracks prior to autoclaving. Ensure that any plastic containers to be put into the autoclave are suitable for high temperature, high pressure conditions, e.g. polycarbonate, PTFE and most polypropylene items. Metal trays are also acceptable.
- Ensure that lids to all containers are loosened to prevent pressure build-up during heating and a vacuum upon cooling.
- Ensure that containers of liquid are no more than ⅔ full.
- Use secondary containment to prevent spillage i.e. put items in trays that will sufficiently catch spills should they occur.
- When unloading the autoclave:
  - Ensure that the autoclave has depressurized prior to opening 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.

17.5 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 biosafety cabinet whenever possible. Equipment such as blenders and stirrers can also produce large amounts of flammable vapours or fine powders depending on the material being used, and therefore should be used within a chemical fume hood.

- Ensure equipment is equipped with safety features that minimize leaking and prevent operation if blades are exposed.
- Ensure equipment is selected appropriately for the task being performed, e.g. non-sparking (intrinsically safe) motors are used when dealing with flammable solvents.
- Ensure that any equipment that could move during use is secured to the bench or floor as applicable.
- Ensure equipment is in good condition prior to use.
- Allow aerosols to settle for at least one minute before opening containers.
- Hearing protection may be required when using sonicators or grinders due to the high frequency or high amplitude sound waves produced.

17.6 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 are only to be performed by trained, qualified personnel. Maintenance service contracts with a qualified repair company obtained through University Purchasing Services should be available for all units. All maintenance is to be documented. To preserve your safety, sample integrity and 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 biosafety cabinet or chemical fume hood as appropriate.
- Decontaminate the outside of the cups/buckets and rotors before and after centrifugation.
- Inspect the o-rings on rotor lids regularly and replace if cracked or dry. Never operate a centrifuge if the rotor lid is missing its o-ring.
- 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 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 ensure that samples are balanced.
- 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.
- **For each rotor, record speed and run time for each run in a logbook such that rotors can be downgraded and discarded as appropriate.**
- If 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.

17.7 Distillation Equipment

Hazards involved with distillation procedures include those corresponding to the use of flammable liquids, heat and pressures other than atmospheric pressure.

- Ensure that joints are secured. Vapour leaks can lead to fire, unnecessary exposure and contamination of the workspace.
- Never distill or evaporate organic compounds to dryness unless they are known to be free of peroxides. See section 13.2.4 for information on the hazards of peroxides.
- Continuously stir the distillation mixture to prevent bumping of the solution which can result in the apparatus blowing apart. The use of boiling chips may also prevent bumping if the distillation is being performed at atmospheric pressure.
- Ensure that the heating source used provides even heating of the solution, e.g. heating mantle, ceramic cavity heater. The addition of a thermometer near the centre bottom of the

distilling flask may provide an early indication of unexpected exothermic decomposition reactions.
- If the distillation is being performed at reduced pressure, evacuate the apparatus gradually to reduce the possibility of bumping.
- After completing a distillation at reduced pressure, cool the system before slowly introducing air. Introduction of air into a hot system may create an explosive environment.
- Solvent stills are to be set-up in the fume hood.
- Reduced pressure distillation set-ups or those involving the use of particularly hazardous materials are to include appropriate shielding.
- Consider using systems designed to shut down if cooling water fails.

17.8 Electrophoresis

The use of voltages of approximately 2000 V and currents of more than 80 mA in electrophoresis procedures create the potential for a lethal 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.
- Ensure electrical interlocks are used.
- 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.

17.9 French or Hydraulic Presses

Presses can be valuable pieces of laboratory equipment; however careful use is necessary to ensure safe operation.

- If being used for cell disruption, care is to be taken to ensure protection against the release of potentially biohazardous aerosols.
- Ensure that loose clothing and long hair is secured, and any other items are clear of the press before operation.
- Ensure that appropriate protective eyewear is worn.

17.10 Gas Chromatographs

Gas chromatography (GC) procedures involve the use of compressed gases and may involve the use of flammable solvents and toxic chemicals. Be sure that you are familiar with the use and handling of compressed gases. See section 14. Familiarize yourself with the hazardous properties as well as the recommended precautionary measures and handling instructions of any hazardous materials being used, by referring to MSDSs or other reliable reference material. The following guidelines provide guidance for the safe operation of GCs.

- Ensure that proper eye protection is worn. GC columns are fragile and breakage could result in small projectiles during handling. As well, samples are prepared in various hazardous solvents that could be damaging to 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 performing any 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. This should be done using a technique that will not damage or sacrifice the integrity of the instrument.
- Depending on the detector, the effluent of the instrument may need to be vented or otherwise filtered, e.g. electron capture, mass spectrometer and other non-destructive detectors. Spot ventilation systems accomplish this.
- Electron capture detectors (ECD) have a radioactive source and therefore need to be registered as part of the University's Radiation program. These detectors are not to be relocated or discarded without permission from the Radiation Safety Officer. Contact the Radiation Safety Officer at x54888 for more information about CNSC requirements.
- Ensure that the instrument and gases are turned off, with the power cord disconnected prior to performing any maintenance.

17.11 Glassware

Proper use of glassware can prevent 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.
- 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 connection easier. Ensure that stopper holes are appropriately sized and carefully insert tubing by gently 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 such that it cannot be easily knocked down.

17.12 Glove Boxes/Glove Bags

Gloves boxes and bags are isolated, fully sealed, containment units, fitted with armholes and gloves such that highly toxic, air reactive or pyrophoric materials can be manipulated safely.

- Generally, glove boxes are operated under negative pressure so that any leakage is into the box. However if operated under positive 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 being used with highly toxic materials, exhaust is to be treated prior to release to the environment. Treatment could involve the use of activated charcoal filters or chemical scrubbers.

17.13 Heating Baths

Heating baths are designed to heat materials to a 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 be as high as 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 bath has cooled before relocation.
- 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 with a non-mercury thermometer to allow a visual check of the bath temperature.
- Do not fill over ⅔ full.
- Take care to not allow water to get into oil baths as violent splattering may result.

Steams 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 regularly; a disinfectant, such as a phenolic detergent, can be added to the water.
- Avoid using sodium azide to prevent growth of microorganisms; sodium azide forms explosive compounds with some metals.
- Decontamination can be performed by raising the temperature to 90^{o}C or higher for 30 minutes once a week.
- Unplug the unit before filling or emptying.

17.14 High Performance Liquid Chromatographs

High performance liquid chromatography (HPLC) procedures often require handling of compressed gas (helium) and flammable and toxic chemicals. Be sure that you are familiar with the use and handling of compressed gas cylinders. See section 14. Familiarize yourself with the hazardous properties as well as recommended precautionary measures and handling instructions of any hazardous materials being used, by referring to MSDSs or other reliable reference material. The following guidelines provide guidance for the safe operation of HPLCs.

- Be sure to 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.
- 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.

17.15 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 introduction of hydrogen.
- Ensure that the safe pressure limit of the vessel is not approached especially when heating.

- At the end of the reaction, purge 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 upon exposure to air. Filter cakes should be immediately transferred to water and purged with an inert gas such as nitrogen or argon.

17.16 Lasers

The use of lasers and the corresponding management of their hazards are to comply with ANSI Z136.1, Safety Policy 851.09.05 and the procedures outlined in the Radiation Safety program. The hazards associated with the use of class 3A, 3B or 4 lasers include eye or skin burns, fire and electrocution. Below are key aspects of laser hazard management:

- Ensure that operation, repair and maintenance are performed by competent, trained and qualified personnel only.
- 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 are never to be altered, disconnected or removed without written approval from the laboratory supervisor.
- Contact the Radiation Safety Officer at x 54888 for more information.

17.17 Mass Spectrometers

Mass spectrometers (MS) require the handling of compressed gases and flammable and toxic chemicals. Be sure that you are familiar with the use and handling of compressed gas cylinders. See section 14. Familiarize yourself with the hazardous properties as well as recommended precautionary measures and handling instructions of any hazardous materials being used, by referring 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 drainage 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 is to be handled as hazardous waste.

17.18 Microtomes

Microtomes are an important tool used in the preparation of sample sections for microscopy and must be handled with care to ensure protection against lacerations.

- Take particular care when installing or removing blades
- Ensure that blade guards remain in place when leaving the microtome for short periods of time.
- Remove blades when finished for the day
- Carry and store blades within a covered container that holds them in place
- Never attempt to catch a dropped blade
- Clamp samples securely prior to sectioning
- Never leave blades on the bench (including blades used for rough trimming)
- Ensure that when the brake is required that it is applied tightly
- Turn off microtome when not in use

17.18 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. (5-gauss line describes the distance from the centre of the magnet where a magnetic field strength of 5 gauss is experienced. This is the strength of a magnet where the field strength is strong enough to act upon ferromagnetic 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 kinds of

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.

- In the event of damage to the magnet, 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 are to complete helium or nitrogen fills. See section 13.4 for the hazards and precautions associated with cryogenic liquids. Appropriate protective equipment including a minimum of safety glasses and gloves are to be worn.
- Oxygen sensors equipped with alarms are recommended in NMR rooms where the release of cryogenic liquid could lead to displacement of the oxygen in the air to critical levels creating the possibility of asphyxiation.
- 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 in otherwise poor condition.
- Use care when handling NMR sample tubes as they are very fragile.
- Do not operate 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.

17.19 Ovens, Hot Plates and Heating Mantles

Ovens are commonly used in the lab to evaporate water from samples, provide a stable elevated temperature environment and 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 are not to be used to heat reaction, sample or general laboratory solutions. The following precautions should be followed to ensure their safe use:

- Ensure that laboratory ovens and hot plates are designed such that they 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 are to be removed from service until repaired. Heating devices whose temperature unknowingly rises above that required could create significant fire hazards.
- Heating mantles are to be used in conjunction with a variable autotransformer and care is to be taken not to surpass the maximum voltage of the mantle as recommended by the manufacturer.
- Discontinue use of any heating mantle whose heating elements have become exposed.

17.20 Ultraviolet lamps

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

- Conspicuously label all UV lights sources 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 at least include a UV resistant face shield, gloves and a lab coat.
- Depending on the situation, shielding of the equipment itself or work area may be warranted.

18. hysical Hazards

18.1 Electrical

Electrical hazards have been mentioned in relation to specific equipment in section 17; however one needs to be aware of general electrical safety practices.

- Inspect electrical cords regularly and have any frayed or damaged cords replaced.
- Extension cords are permitted for temporary set-ups only.
- "Piggy-backing" of extension cords is prohibited.
- Ensure that electrical equipment is located to minimize the possibility of it being affected by spills, floods, condensation etc.
- Ensure laboratory personnel are aware of power shut-offs.
- Protect against accidental contact with exposed electrical circuits.
- Use of ground fault interrupter circuits is preferable in receptacles located near sinks.
- Electrical plugs are never to be modified in any way.

- Adapters to allow 3-prong plugs to be used with 2-prong outlets are not permitted.

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), Entela, 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.

18.2 High Pressure and Vacuum

Working with pressures other than atmospheric, creates additional stress on the apparatus involved, of which glassware is of particular concern. Risk of explosions and implosions needs to be minimized and precautions are to be taken in the event that they occur.

- Use glassware suited for high pressure or vacuum (e.g. thick walled).
- Ensure that precautions are taken to minimize flying glass in the event of an implosion/explosion, e.g.:
    - Wrap glassware in a criss-cross pattern with strong adhesive tape.
    - Use safety coated glassware.
    - Use wire screening or suitable mesh to cover flasks.
- Conduct work behind a safety shield.
- Ensure that glassware is not strained and is appropriately secured.
- Include pressure relief valves in apparatus set-up for high pressure work.
- Before opening a desiccator under vacuum, ensure that the interior pressure has returned to atmospheric pressure.

18.3 Machine Guarding

Injuries can occur from contact with rotating or moving parts as well as pinch points found in various mechanical equipment and instrumentation found throughout laboratories.

- Laboratory personnel are to be aware of emergency shut-offs for all equipment.
- Manufacturer installed guards and safety interlocks are not to be removed or modified without written approval from the laboratory supervisor. This documentation is to be maintained and include the reason the modification is required.
- Other equipment containing moving or rotating parts or pinch points not equipped with manufacturer installed guards is to be appropriately guarded so as to protect the operator.

19. Ergonomics

Awkward postures, excessive forces, high repetition and contact stresses can all lead to ergonomic related injuries. Laboratory personnel should be aware of their body positioning and take precautions to ensure proper design and set-up of work to minimize the risk of injury. Contact OHW at x54823 for ergonomic assessments.

20. Laboratory Decommissioning

Laboratory supervisors are to ensure that laboratories to be vacated for the purpose of renovation, re-occupation or demolition are appropriately decontaminated and decommissioned such that the facilities are free from physical, chemical, radioactive and biological hazards and are safe for subsequent contractors and/or occupants. The Biosafety and Radiation Safety programs should be consulted for decommissioning requirements of labs with biosafety and/or radioactive hazards.

- Chemical containers are to be labelled and sealed appropriately.
- Laboratory glassware is to be empty and clean.
- Equipment including, but not limited to, refrigerators, autoclaves, ovens, freezers, incubators, fume hoods and storage cabinets are to be cleaned out and appropriately decontaminated.
- All chemicals within equipment are to be drained from the equipment (e.g. pump oil).
- Lab benches and fume hood work surfaces are to be washed down.
- Compressed gas cylinders that are to be moved must have regulators removed and caps secured. If possible, compressed gas cylinders are to be returned to the supplier and arrangements for future deliveries to the new site made if applicable.
- Ensure that hazardous waste is disposed of according to proper procedures. Laboratory supervisors will be responsible for costs associated with any unknown chemical wastes that cannot be sufficiently identified or categorized without the assistance of an outside contractor.
- Ensure that non-hazardous waste is disposed according to proper procedures and not left in the laboratory.
- Laboratory supervisors will be responsible for costs associated with disposal of hazardous materials and decontamination of equipment and facilities.
- For those laboratory supervisors that are leaving their position at the University for any reason (retirement, other employment etc.), ensure that associated common lab areas are cleaned out of material and equipment belonging to the departing employee.

The laboratory supervisor is responsible for completing Laboratory and Equipment Decontamination and Decommissioning Report(s) as applicable, and making the necessary arrangements to have the laboratory inspected and the report signed by both the chair/head of the department and the appropriate representative(s) from EHS. Report forms are available at http://www.uoguelph.ca/ehs/forms_by_alphabetically.

Appendix A – Changes from the Previous Edition

Changes to the previous edition, (2008) include:

- Minor edits and clarification to the text throughout; updated resources and website links
- Section 4 – Addition of the locations of first aid stations. Clarification of follow-up procedures with medical professionals for students
- Section 9 – Removal of reference to Emergency Contact/Hazard sign as it is not currently available.
- Section 9 – Addition of Emergency Procedures posters
- Section 9 – Incorporation of emergency response procedures for regional campuses, research stations and Laboratory Services, AFL
- Section 9 – Identification of First Aid Stations on the Guelph campus
- Section 10 – Replacement of Figures B (Fire Triangle)
- Section 10 – Update of annual inspection procedures for fume hoods
- Section 12 – Update of annual testing of fume hood performance and alarms
- Section 12 –Replacement of Figure C (Chemical Fume hood)
- Section 13 - Clarification of peroxide forming materials
- Section 13 - Addition of nanomaterials
- Section 15 – Inclusion of legislation for chemical storage
- Section 15 – Inclusion of requirements for flammable and combustible storage rooms
- Section 16 - Clarification and further description of tests used in the characterization of unknown wastes
- Section 17 - Addition of microtomes

Changes to the 2nd edition, (2011) include:

- Minor edits and clarification to the text throughout; updated resources and website links