QUEEN'S UNIVERSITY DEPARTMENT OF CHEMISTRY

SAFETY MANUAL

February 2022

IN CASE OF EMERGENCY:

FROM WITHIN THE UNIVERSITY 36111

FROM OUTSIDE THE UNIVERSITY 613-533-6111

OR PUSH THE RED BUTTON ON THE YELLOW BOX

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1. INTRODUCTION

Safety is the responsibility of everyone who works in the Department of Chemistry. This includes all faculty, staff, graduate students, researchers and visitors to the Department. This manual is intended to cover many of the common or general hazards associated with work in the Department and must be read and adhered to by everyone working in the Department. It cannot be assumed that the warnings or rules laid out in this manual are necessarily complete for dealing with specific chemical hazards; additional information or measures may be required and the appropriate information sources should be consulted.

- ***It is the responsibility of individual supervisors to ensure that the necessary procedures and protocols are established and followed in their respective work areas.***
- ***It is the responsibility of workers to follow prescribed procedures and protocols when dealing with hazards in the laboratory.***

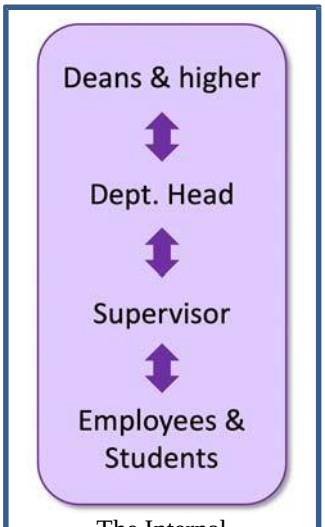
Personal safety depends upon a positive attitude towards safety as well as good, informed judgment on the part of each individual working in the Department. Most health and safety problems in the laboratory can be avoided by practicing good housekeeping and common sense based upon informed knowledge of the hazards.

A safe working environment is achieved through responsible, self-motivated activity.

1.1 Responsibility

Under the Occupational Health and Safety Act, management (the university and the department), the supervisors, and the individual employees and students are within the Internal Responsibility System (IRS, see figure) and all have responsibilities. Supporting organizations, such as safety committees and the Department of Environmental Health and Safety are available for advice and support.

The **Department** (as part of "Management" along with higher levels of the university) has responsibility and authority for maintaining appropriate standards for health and safety within the Department. To this end the Department sets out the appropriate standards and procedures in the Department Safety Manual, provides basic training in safety for the chemical laboratory and performs inspections of the workplace.



The Internal Responsibility System

Supervisors are responsible for ensuring that individuals under their supervision a) have a safe environment in which to work, b) know and follow the Department safety rules, c) are made aware of the specific hazards associated with their work, and d) have available the appropriate procedures and safety equipment for dealing with these hazards.

Individuals must work safely according to the procedures outlined by the Department and the individual's supervisor, must maintain a safe working environment through good laboratory practice and good housekeeping, and must notify their supervisor or the

Department of any defects in equipment or protective devices, or of the existence of hazards in the workplace.

The rights and responsibilities of supervisors and workers, as defined by the Occupational Health and Safety Act, are described in Appendix 1.

1.2 General Rules

1.2.1 Managing Hazards

- Know and follow safety rules, procedures and protocols.
- If you're unsure of the hazards or how to complete the work safely, ask your supervisor rather than continuing with the work.
- Be aware of hazards, and the procedures for dealing with those hazards, before you start your work. A risk assessment of the work would help in identifying and becoming knowledgeable about the hazard.
- Maintain a tidy workplace (see photo below).
- WHMIS training is mandatory for anyone who works with or who may be exposed in the course of their work to a hazardous material.
- Anyone working in a lab who becomes pregnant should inform their supervisor so that an assessment of potential risks may be carried out.
- Always know the hazardous properties of materials being used.
- Always wash hands ***thoroughly*** before leaving the laboratory.
- Never eat, drink or apply cosmetics in laboratories.
- Never perform unauthorized experiments.
- Do not perform any hazardous work if you are distracted, unprepared, or physically/ mentally/emotionally unwell.
- Never engage in pranks, practical jokes, or other acts of mischief.

Accidents are more likely to happen if your work station is messy.

1.2.2 Safety Equipment & Signage

- Familiarize yourself with all safety equipment and procedures in your work area (telephone, exits, fire extinguishers, fire alarms, safety shower, eyewash fountain, first aid kit, evacuation routes).
- Post suitable warning signs if a specific hazardous situation exists; include the name and phone number of individual(s) responsible.
- Do not block access to emergency exits, electrical panels, or emergency equipment (eyewashes, safety showers, first aid kits, spill kits, fire extinguishers, etc.).

1.2.3 Doors and Access

- Fire doors must be kept closed at all times; automatic (self-closing) fire doors must not be blocked from closing.
- Research labs must keep lab doors closed to effect proper ventilation of the lab.
- Keep your work area locked when unoccupied to avoid unauthorized entry.
- No bicycles, rollerblades or pets in the building.
- Personal Protective Equipment and Attire
- Always wear proper eye protection for the task you will be performing (e.g. safety glasses, prescription glasses with side shields, laser goggles).
- Always wear appropriate protective clothing (lab coats in wet chemistry labs)
- Never wear open-toed shoes, high-heeled shoes or sandals
- Always wear long pants (no shorts, skirts, short dresses, or capris)
- Don't wear headphones. You need to be able to hear if something is wrong, like a pump that has run out of oil or a colleague who's been hurt.

1.3 Contacts

• For an emergency, call 36111 (or 613-533-6111 from a cell phone) (or push the RED button)

• For ruptured pipes, floods, broken windows, exterior door malfunctions, snow removal, icy conditions, etc., contact Facilities (PPS)

- Mon-Fri 7 am to 4 pm: 77301 (or 613-533-6757)
- at other times: 36080 (or 613-533-6080)

• For safety questions, your first contact should be your supervisor. Other sources of information include this manual and the many materials at the website of the Dept of Environmental Health and Safety. For more information, contact the departmental manager or the chair of the safety committee.

Department of Chemistry		
Lindsay Lee	Dept Manager & Dept Safety Officer	36662
Dr. Philip Jessop	Chair, Dept Safety Committee	33212
Dr. Richard Oleschuk	Head	32624
Department of Environmental Health and Safety		
Mr. Dan Langham	Director	32999

1.4 Safety Data Sheets

The provision by chemical manufacturers of safety data sheets (SDS, also known as Material Safety Data Sheets, MSDS) for hazardous materials is one means of communicating information on chemical hazards. In addition, various electronic SDS databases are available at Queen's University through links on the Department of Environmental Health and Safety Website. https://safety.queensu.ca/chemical/chemwatch-sds-safety-data-sheets

Read the SDS (the most recent version) and familiarize yourself with the hazards posed by the chemical, recommended precautions, and emergency procedures **BEFORE you use the chemical**.

1.5 Policies and Standard Operating Procedures Available from EH&S

In addition to the health and safety standards set by the Department of Chemistry, the

Department of Environmental Health and Safety at Queen's University has established a set of policy statements and standard operating procedures for the University. They are listed at this website:

https://safety.queensu.ca/policies-and-standard-operating-procedures

The more chemistry-relevant documents available at that website include:

- Laser Safety
- Radiation Safety
- Autoclaves
- Laboratory Decommissioning
- Respirator Protection
- Refusal to Work
- Compressed Gas Cylinders
- Chemical Storage
- Spill Response Procedure
- Health and Safety Management System
- Environmental Management
- Workplace Violence and Harassment
- Transportation of Dangerous Goods
- X-Ray Safety
- Fume Hoods
- Eyewash Stations & Safety Showers
- Lab coats
- Lab Chairs and Stools
- Ladder Safety
- Sharps & Glassware Disposal
- Storage in Building Corridors
- WHMIS Training
- Policy Statement on Health & Safety
- Off-Campus Activity Safety Policy
- Hazardous Waste Disposal Procedures
- Mold
- Laboratory Flammable and Combustible Liquid Handling Procedures
- General Flammable and Combustible - Liquid Handling Procedures
- Decommissioning of Research Equipment/Furniture
- Health & Safety Roles & Responsibilities
- Departmental Safety Bulletin Boards

There are also documents on many other safety topics such as biohazards.

1.6 Signage in Chernoff Hall

There are a variety of signs posted around the building (Fig. 1). Read those closest to your work area to familiarize yourself with hazards, requirements, safety equipment locations, and exit routes. The symbols used in these signs are explained in Figures 2, 3 and 4.

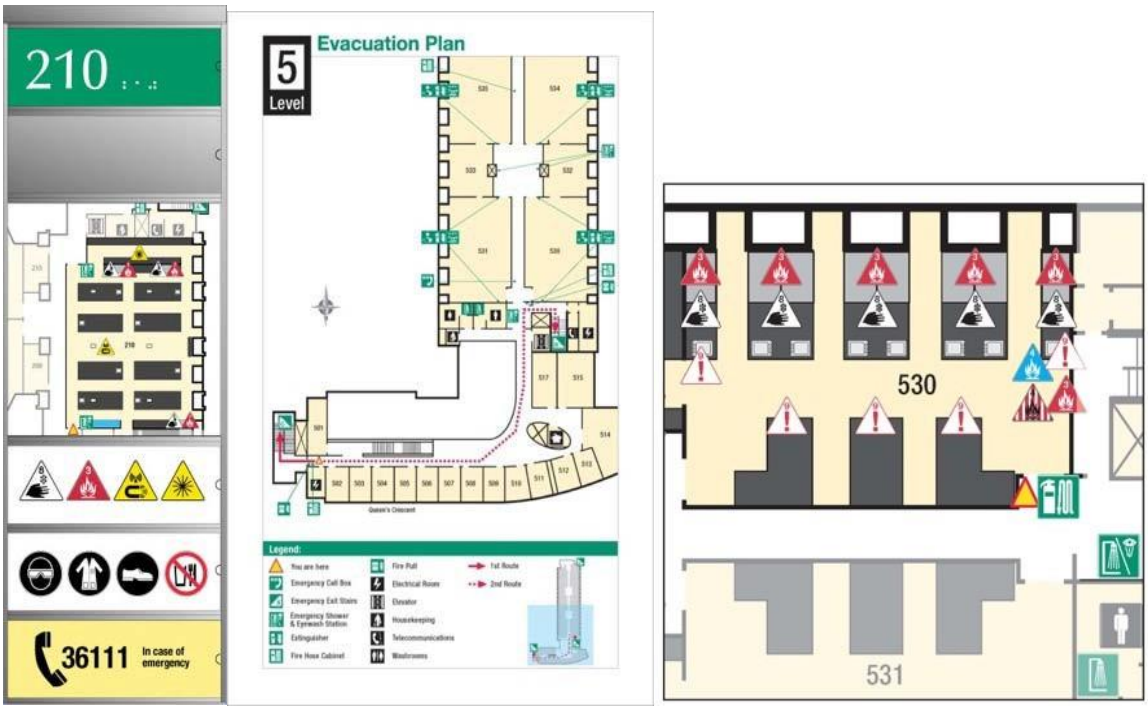


Figure 1. Examples of safety signage in Chernoff Hall: a door sign, an evacuation plan, and a lab room map.

Figure 2. Green symbols representing the locations of safety equipment.

	**NO FOOD OR DRINK** Absolutely no food or drink permitted in this space.
	**NO GLOVES** No lab gloves permitted beyond the posted sign (typically on the inside of each lab door indicating they are not to be worn beyond the lab).
	**RADIOACTIVITY TAG** A dosimeter provided from Health Canada must be worn at all times.
	**RESPIRATOR** A respirator with the correct cartridges must be worn at all times. All respirator users must have appropriate training for proper fit and use before using.
	**SHOES REQUIRED** Proper shoes that cover the foot are required (no open toed shoes permitted in any lab space).

	**EYE PROTECTION** Goggles must be worn at all times.
	**FACE SHEILD** Full face shield must be worn at all times.
	**FOOT PROTECTION** CSA Approved foot protection must be worn at all times.
	**GLOVES** Gloves must be worn at all times (check a glove chart to ensure that you are using the right glove for the right task)
	**HEAD PROTECTION** CSA Approved hard hat must be worn at all times.
	**LAB COATS** Lab coats or outer protective layer must be worn at times.

Figure 3. Black & white symbols representing required personal protective equipment (PPE) and other restrictions.

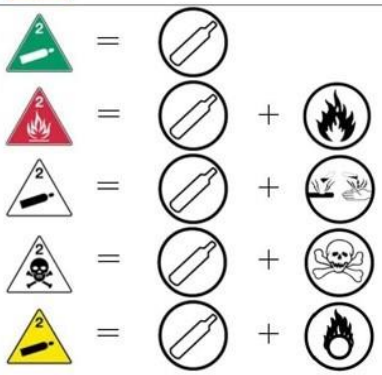
EXPLOSIVES	
COMPRESSED GASES	
FLAMMABLE LIQUIDS	
FLAMMABLE SOLIDS	

Figure 4. Warning symbols indicated hazards.

1.7 Other Resources

This manual will describe general procedures and protocols for dealing with common hazards in the chemical laboratory. For detailed information on the handling and disposal of specific chemical substances, an excellent list of online resources has been compiled by the Queen's University Libraries. https://guides.library.queensu.ca/chemistry/health-safety This website includes online books, databases, and links to SDS.

2. HAZARDS ASSOCIATED WITH SPECIFIC CHEMICALS

There are over 50 million known chemical substances with more being continually discovered; the hazardous properties of most of these substances have not been investigated.

2.1 Corrosive and Caustic Chemicals

Corrosive chemicals cause visible destruction or irreversible alteration to living tissue. Common acids and bases are the most common corrosives encountered, but other chemicals such as Br_2 are also extremely corrosive. Organic acids and bases, because they are more hydrophobic and can therefore penetrate skin readily, can be quite corrosive even if they are not "strong" acid or bases (e.g. acetic acid, triethylamine).

- use appropriate personal protective equipment and fume hood ventilation when working with strong acids and bases, and other corrosive substances
- concentrated acids and bases should always be diluted by addition to water due to the large heat of solution for these compounds
- safety glasses do not provide complete eye protection from chemical splashes; wear appropriate safety goggles or splash shields when working with corrosive substances
- corrosive gases (e.g. HCl, SO_2, NO_2, NH_3) should be in smaller (not full-sized) gas cylinders and those cylinders should be firmly secured and used *inside* a fume hood rather than in front of the hood.

NOTE: some specific acids such as HF (extremely toxic) and $HClO_4$ (powerful oxidizer of organics) require special handling procedures. Consult the appropriate references and your supervisor before working with these chemicals.

2.2 Pyrophoric Compounds

Chemicals which can ignite on exposure to air or water include the following:

- Some organometallics (e.g. Grignard reagents, alkyl lithium, alkylaluminiums, metal carbonyls, dialkylzinc, trialkylborane)
- Some hydrides (NaH, $NaBH_4$, $LiAlH_4$, SiH_4, B_2H_6, PH_3)
- Finely divided metals (Fe, Al, Bi, Zr, Zn, Mg, Ca, Raney nickel)
- Some heterogeneous catalysts, especially after use in a reducing environment (Raney nickel, Pd on carbon, copper fuel cell catalysts)
- Electropositive metals (Na, K, Rb, Ca, Ce)
- White phosphorus

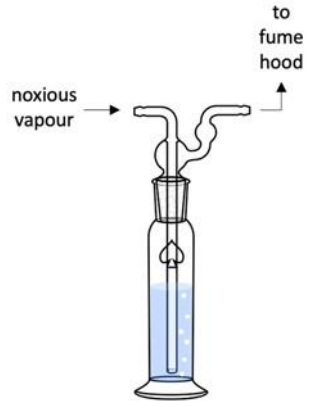
Special handling, storage and disposal procedures must be established in laboratories where these substances are in use (see section on **Flammability** and Appendix II - **Incompatible Chemicals**).

- store these chemicals in a location separate from other chemicals in the laboratory and in containers appropriate for the purpose
- use equipment appropriate for the hazards associated with these substances including inert atmosphere techniques. Approach your supervisor if you need to be trained on inert atmosphere techniques.
- class "D" fire extinguishers (metal fires) or dry sand must be present in laboratories where these substances are in use; do not use "C" class fire extinguishers (CO_2) on metal fires. The yellow fire extinguishers currently available in the department are intended for lithium fires and are not guaranteed to be effective for other burning metals.

2.3 Noxious Chemicals

Certain classes of compounds such as volatile carboxylic acids, phosphines, thiols (mercaptans) and related sulfur-containing compounds are characterized by a particularly noxious odour

- these compounds must be used with adequate ventilation (fume hoods)
- vapours containing such compounds should be vented through a trap or scrubbing bath that contains either a base (for carboxylic acids) or bleach (for phosphines, thiols, and related sulfur-containing compounds).
- whenever compounds of this type are used they may be inadvertently released through the ventilation system into the local atmosphere. Consequently, both the Department Safety Officer and the Emergency Report Centre must be notified in advance of the use of these chemicals



Use a trap to catch noxious vapours before they can go up the fume hood.

2.4 Lachrymators

Lachrymators are substances which react with moisture in the eyes and mucous membranes to cause tear formation (e.g. halogenated aldehydes/ketones/esters, thionyl chloride, acrolein, 4-bromobenzyl bromide, maleimide). These must be used with adequate ventilation (fume hood) and stored in well-sealed containers.

2.5 Incompatible Chemicals

Accidental contact of incompatible chemicals can lead to fire, explosion and/or the release of highly toxic substances. The magnitude of the problem usually increases with the quantity of chemicals being stored. Prudent practice requires that incompatible chemicals be stored in separate locations to minimize the risk of accidental mixing. Appendix II **Classes of Incompatible Chemicals** lists some general groups of incompatible chemicals; further information on specific chemicals may be obtained from references such as *Hazards in the Chemical Laboratory*, by L. Bretherick or *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*, National Research Council, National Academy Press, 1995.

Oxidizers (e.g. chromates, halogens, peroxides) and **reducers** (e.g. metals, metal hydrides, phosphorus, sulfur) are incompatible with each other and should be stored in separate cabinets or on separate shelves. Strong oxidizers should also be separated from flammable liquids.

2.6 Toxic Chemicals

A wide range of substances are present in the chemical laboratory which present several types of health risks:

- acute toxins (most chemicals are acutely toxic if the dose is large enough; beware of compounds where the necessary dose or the LD_{50} is particularly small)
- neurotoxins (damage to nerves over multiple exposures)
- hepatotoxins (damage to liver over multiple exposures)
- nephrotoxins (damage to kidneys over multiple exposures)
- mutagens (cause DNA modification, including potentially cancer)
- carcinogens
- teratogens (cause birth defects)

- miscarriage triggers
- chemicals which cause other reproductive problems for men or women
- irritants
- sensitizers (causes one to develop an allergic reaction after repeated exposure)

Toxic substances may enter the body by inhalation, absorption, ingestion and/or injection. Appropriate protective measures must be taken to prevent exposure and which are consistent with permissible exposure limits for a specific substance. For example:

- Wear appropriate personal protective equipment (PPE) such as gloves
- Where available, antidotes for poisons must be present during usage of acute toxins, but if possible ask for advice over the phone before administering antidotes. In the case of HF exposure, however, immediately apply calcium gluconate gel.
- Notify your supervisor if you have or develop a sensitivity to a particular chemical
- Notify your supervisor if you are pregnant or planning to become pregnant
- Never store, prepare or consume food or drinks in the lab.
- Never store or use cosmetics (including Chapstick), food containers, or eating utensils in a lab.
- Food or beverages brought into the lab for research purposes must be clearly marked as "NOT FOR CONSUMPTION." A label for that purpose is available from Science Stores (see image).

2.7 Designated Substances

In the Occupational Health and Safety Act there are a number of chemicals classified as "designated" and there use in the workplace may be either prohibited limited, controlled or strictly regulated. A Designated Substances Assessment must be completed when using any of the substances listed below and submitted to EH&S for review to assess the likelihood of worker exposure. Contact EH&S to obtain a copy of the Designated Substances Assessment workbook. The following are designated substances:

Acrylonitrile	Coke oven emissions	Mercury
Arsenic	Ethylene oxide	Silica powder
Asbestos	Isocyanates	Vinyl chloride monomer
Benzene	Lead	

Acrylonitrile, benzene, isocyanates, and vinyl chloride monomer are all volatile organic materials and must be used with adequate ventilation (fume hood) to prevent exposure through inhalation and with appropriate protective equipment to prevent exposure through skin absorption. These materials can be disposed of in the normal liquid organic waste stream.

Substances containing **arsenic, lead or mercury** must be handled in an appropriate manner to prevent exposure through inhalation or absorption. All chemical waste containing arsenic, lead or mercury must be collected and properly labeled for disposal by the Department of Environmental Health and Safety.

Elemental mercury is used in many types of apparatus, in particular mercury-filled thermometers. Mercury spills from broken equipment should be cleaned up immediately (mercury spill kits are available from the Department of Environmental Health and Safety). Broken thermometers are collected by lab technicians, who will recover the mercury from the thermometers before disposal.

Silica powder, including chromatography grade silica, is a respiratory hazard and should be handled in a fume hood when dry. Used silica should be stored in sealed and labeled containers and then sent for disposal (see "Solid Wastes" in Section 7.3).

2.8 Flammable Chemicals

2.8.1 Definitions

A liquid's flash point is the lowest temperature at which the vapours of the liquid can ignite if a spark or ignition source is present.

The Ontario Fire Code defines flammable liquids as those liquids having a flash point ≤ 37.8 ˚C and combustible liquids as those having a flash point > 37.8 ˚C ≤ 93.3° C. Many liquids with flash points > 93.3 ˚C will still burn, however, if they end up in a fire. Other regulations and other governments have different definitions of the word "flammable", but for work at Queen's the above definitions should be used.

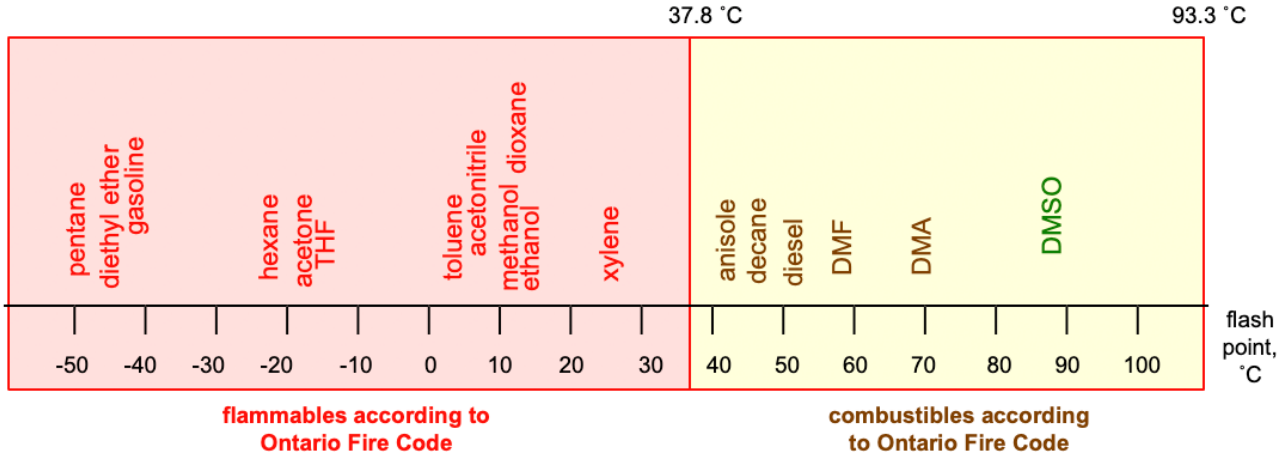


Figure 5. Common solvents sorted by their flash points.

2.8.2 Storage of Flammables

The quantities of flammable and combustible liquids that may be stored in laboratories are governed by the Ontario Fire Code. It is the responsibility of every research supervisor to ensure that flammable and combustible solvents present in their labs are handled, stored and disposed of in accordance with this Code. Classification of flammable solvents can be found in the OFC section **4.1.2.1. (1).**

The main points to be noted are:

1. Containers for storing solvents or solvent waste must not exceed 5 L capacity; exceptions are waste solvent containers with flame arrestors ((20 L, must meet ULC/ORD-C30), and stainless-steel cylinders (e.g. Aldrich Pure-Pac®, 18 L) used in solvent purification systems in accordance with the manufacturer's specifications. (OFC pt 4 sec. 4.12.3.1(1))
2. A total of 300 L of (flammable + combustible) solvents may be stored in the open lab. For that reason, *both* flammable and combustible liquids (Fp < 93.3 ˚C should be stored in flammables cabinets.
3. Of the 300 L total, the maximum allowable amount of flammable solvents in the open lab is 50 L;
4. Flammable solvents stored in the open lab cannot be in containers > 1 L capacity. Similarly, flammable waste solvents cannot be collected in the open lab in containers greater than 1 L capacity. (OFC pt 4 sec. 4.12.3.1(2)).
5. Flammable waste solvents in a safety container are included in the limits in sentence 2 and 3

unless the safety container is inside a flammable's cabinet.

6. Quantities in excess of sentence (2) MUST be stored in an approved flammable storage cabinet.
7. Quantities in an approved flammable storage cabinet cannot exceed the storage capacity of the cabinet. No flammables cabinet, no matter how large, may contain more than 500 L of flammable/combustible liquids. No lab may have more than 1500 L of flammable/combustible liquids in flammables cabinets.
8. All containers for storing flammable + combustible liquids must be kept closed when not in use.

Note that the above limits (50 L and 300 L) include the entire volume of each container, not just the volume of liquid therein. The "container" could be a bottle, can, wash bath, spray bottle, still, or even an experimental apparatus.

2.8.3 Static Electricity and Spark Hazards

Protection from static discharge must be addressed in particular when handling flammable solvents; this risk is increased during periods of low humidity. Proper grounding of containers and equipment will significantly reduce this risk. Always connect (electrically bond) containers when transferring flammable liquid if the container is a) larger than 5 US gallons (19 L) or b) made from an electrically conductive material such as a metal.

Common potential sources of sparks and static discharges are:

- ungrounded metal tanks and containers
- clothing or containers made of plastic or synthetic materials
- high pressure gas cylinders upon discharge
- control systems on hotplates
- brush motors such as those in a stir plate or forced air dryer

2.9 Self-Reacting Chemicals including Peroxides

Self-reacting chemicals may be heat, shock or friction sensitive and can react violently as a consequence, e.g. acetylene and acetylides, azides, diazonium salts, nitro compounds, chlorates and perchlorates, peroxides. Special handling, storage and disposal procedures must be established in laboratories where these substances are in use.

Organic peroxides are a special class of compounds which pose unusual stability problems. These peroxides are among the most hazardous chemicals normally handled in chemical laboratories and in manufacturing. As a class, organic peroxides are low-power explosives and may be sensitive to shock. Peroxides have a specific half-life, or rate of decomposition, under a given set of conditions. A low rate of decomposition may auto-accelerate into a violent explosion, especially in bulk quantities of peroxides. They are sensitive to heat, friction, impact and light as well as to strong oxidizing and reducing agents. All organic peroxides are extremely flammable and fires involving bulk quantities of peroxides should be approached with extreme caution.

The following precautions should be followed when handling organic peroxides and hydroperoxides:

- study and follow all precautions specified by the manufacturer
- store the peroxides at the minimum safe temperatures to minimize the rate of decomposition; do not refrigerate or store liquid or solutions of peroxides at or below the temperature at which the peroxide freezes or precipitates - peroxides in the solid state have increased sensitivity to shock and heat.
- do not store reactives or peroxides beyond the expiry date specified by the manufacturer.
- limit the quantity of peroxide handled to the minimum amount required; do not return

unused peroxide to the stock container

- clean up all spills immediately by recommended procedures
- the sensitivity of most peroxides can be reduced by dilution with inert solvents such as aliphatic hydrocarbons (e.g. mineral oil) but never with acetone or other ketones
- avoid using peroxides in volatile solvents when it is possible that the solvent will vaporize and thereby increase the concentration of the peroxide
- never use a metal spatula with organic peroxides; contamination by metals can cause explosive decomposition - use plastic or ceramic spatulas
- avoid friction, grinding and impact; never use glass containers with screw cap lids or glass stoppers, instead use plastic bottles and sealers
- do not use open flames, sparking equipment or intense heat sources near peroxides
- avoid ingestion, inhalation and skin contact since many peroxides are irritants

A common method of disposal of liquid organic peroxides is dilution to <10% by weight in a suitable nonvolatile hydrocarbon solvent (often mineral spirits or mineral oil) prior to sending out the material (through the Department of Environmental Health and Safety) for disposal by incineration. Check the manufacturer's recommendations prior to disposal of any specific peroxide.

Monomers can also self-react, giving thermal-runaway polymerizations. They are normally shipped with an inhibitor, but if the inhibitor has been removed or if the sample has passed its expiry date (the inhibitor decomposes over time), then exothermic polymerization could happen at any time.

2.10 Peroxide Formers

2.10.1 Definitions

A peroxide former is a chemical that is not a peroxide but tends to be converted to peroxides over time. Most but not all peroxide formers are organic compounds. Those that form peroxides quickly must be disposed of within 3 months of receipt. Those that form peroxides more slowly must be disposed of within 12 months of receipt. However, if testing for peroxides shows that the liquid is free of peroxides then the date of disposal may be postponed by an additional 3 or 12 months.

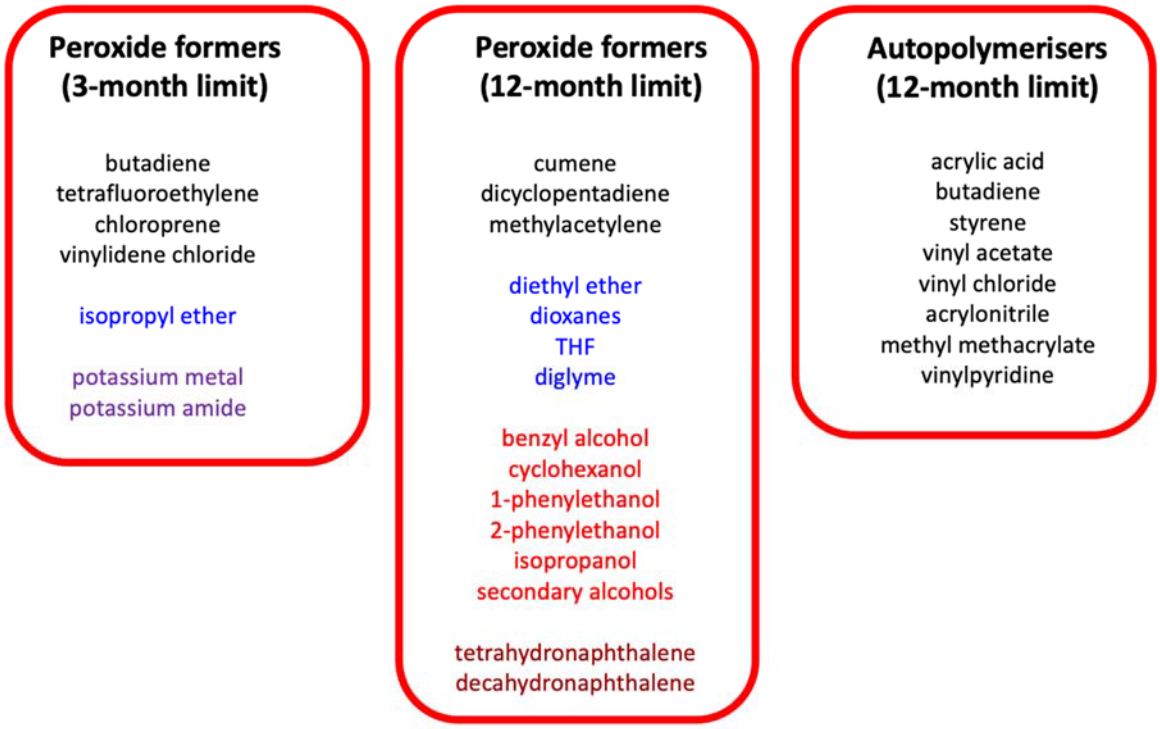
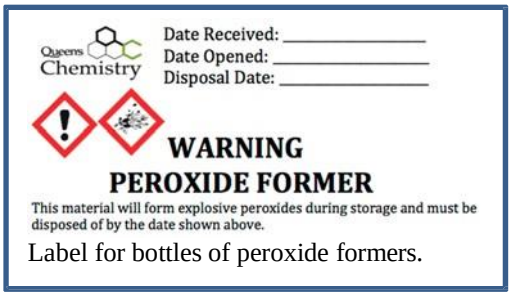


Figure 6. Common peroxide formers.

2.10.2 Precautions



Label for bottles of peroxide formers.

• date the bottle upon receipt. See the label that is available from Science Stores.
• discard or test after 3 or 12 months
• if you choose to test, then mark the date of the passed test and retest frequently thereafter.
• do not purchase large amounts.
• never distill a peroxide-former to dryness. Stop the distillation before half of the liquid is gone.
• do not store a peroxide former past the 3- or 12-month period unless tested and dated.
• Never open an old or crusty bottle of a peroxide former. Peroxides can crystallize in the threads of the cap and may detonate when you attempt to open the cap.

Never distill a peroxide-former past the 3- or 12-month period unless tested

2.10.3 Testing for Peroxide Content

The test strips are most accurate for aqueous solutions of H_2O_2. If you want to use them to determine whether your peroxide-former has formed some peroxides, then do the following: Dip the indicator end of the strip into a small sample of the organic liquid for a second, then remove it and shake off any excess liquid. Wait for a few seconds until the solvent evaporates and add 1 drop of water. The test should not be considered to be quantitatively accurate (for that purpose, you can use the method described in Fábos et al. *Energy Environ. Sci.*, 2009, **2**, 767).

If you find that your peroxide former does not contain any peroxides, then you may write on the label (or a new sticky label) that the contents were tested for peroxides. Specify the date of the test. This allows you to keep the chemical for another 3 or 12 months, depending on which class of peroxide formers it belongs to.

Peroxide test strips.

2.10.4 What to Do if You Find an Old Bottle

If you find an old bottle of peroxide former that is known or suspected to be well past its 3- or 12-month expiry date, **DO NOT MOVE IT OR OPEN IT**. Leave it where it is. Fill out the waste disposal form and add "Caution! Old peroxide former, risk of explosion" to the form. The waste disposal company will determine the best way to proceed.

2.11 Cryogens

2.11.1 Risks of cryogens

Cryogens are gases that are liquified or solidified due to low temperature rather than elevated pressure.

While frostbite may seem to be the most obvious risk of cryogens, explosions due to overpressurization are potentially deadlier. Liquid nitrogen, if it boils, takes 682 times more volume in the gas state than it did in the liquid state. This ratio is called the expansion ratio. If the cryogen is allowed to warm up while inside a closed container, the volume cannot increase, so the pressure will increase instead, by a similar ratio. For more information, see Section 4.7 on Cold Traps.

Risks of cryogens

- Frostbite (Don't spill on clothes, shoes or bench)
- Asphyxiation (Don't store a cryogen in an enclosed space. Don't travel with a cryogen in an elevator. Use an oxygen monitor if needed – see below)
- Overpressurization (don't seal a container of a cryogen)
- Condensing liquid oxygen (which may then be harmful due to supporting combustion or to uncontrolled expansion inside glassware when the coolant is removed)
- Condensing liquid argon (which may then be harmful due to uncontrolled expansion inside glassware when the coolant is removed)
- Metal or plastic embrittlement (steel, for example, is brittle at liquid nitrogen temperature)
- Dewar or vacuum flask breakage

Coolants above 120 K (-153 ˚C) such as dry ice (-78 ˚C) are not technically considered to be cryogens, but they share some of the same risks such as causing frostbite. Dry ice is

frequently used in conjunction with a cooling liquid. These cooling systems can also cause tissue damage due to extreme cold. The proper choice of a cooling liquid presents problems since a nontoxic, non- flammable, low viscosity, low volatility liquid does not exist. In general isopropanol (flash point 11°C) is preferable to acetone (flash point -18°C) due to a higher flash point but still represents a fire hazard. A 3:2 mixture of ethylene glycol to water which is thinned with isopropanol is an alternative cooling liquid with reduced flammability.

The phase separator on a liquid nitrogen supply tube.

2.11.2 Is an oxygen monitor needed in your lab?

The supervisor should calculate how much nitrogen gas would be released if your liquid nitrogen evaporated into the room. If the volume of released N_2 would be greater than $^1/_5$ of the room volume, then you need an oxygen monitor. Here is an example calculation.

EXAMPLE #1: A tank carries 230 L of liquid N_2. A worker is planning to use that tank in a 40' x 36' x 10' room. Is an oxygen monitor required? ANSWER: The room volume = 40' x 36' x 10' = 14,400 ft^3
$^1/_5$ of room volume = 2,880 ft^3
expansion ratio for N_2 = 682
volume of released N_2 gas = 682 x 230 L x 0.035 ft^3/L = 5,490 ft^3
Therefore vol of N_2 > $^1/_5$ of room volume. An oxygen monitor is needed!

2.11.3 Handling cryogens

Wear appropriate PPE when working with cryogens.

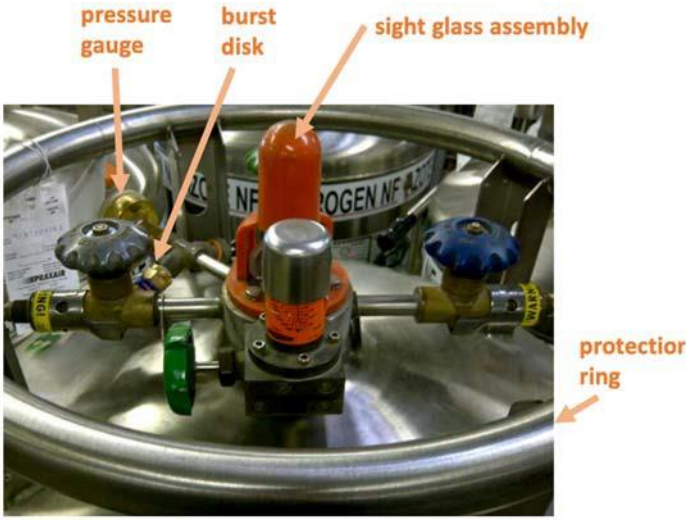
- Clean *loose-fitting* leather insulated gloves with gauntlets. Do not wear gloves made of rubber, nitrile or similar materials.
- Cuff-less long pants worn outside of shoes or work boots
- Long sleeve shirt, jacket, lab coat, or apron
- Closed toe shoes
- Clear face shield

How to fill a dewar flask or vessel with liquid nitrogen from a large container

- Inspect for damage to vessel that would prevent safe filling (cracks, contaminants, etc.)
- Inspect filling hose from end to end. Ensure it is threaded on properly to supply container
- Check condition of the phase separator at the end of the hose. If you're filling a small vessel, the separator might be too large to use.
- Make sure your dewar is firmly placed on floor
- Ensure that the filling area is clear and well ventilated
- Check the oxygen monitor (if applicable)
- Place the hose with the phase separator just inside mouth of vessel, 1-2 inches below the neck of the dewar
- Slowly open the liquid designated valve on supply container and allow a small amount of liquid to flow into vessel
- Once vessel has cooled slowly increase flow.
- Weight is the only accurate way to determine when the dewar is full.
- Close the liquid valve on the supply container
- Replace the vented stopper supplied with dewar

Handling cryogen tanks

- Store the container in a well-ventilated area
- Ensure the container has proper caution labels
- Ensure the container has gas-specific value connections
- Don't use adapters
- Do not lift or hoist by the protection ring.
- Open valves slowly
- Do not accompany the container in an elevator
- Use 2 people to transport tank.



Key parts on the top of a liquid nitrogen tank.

2.12 Compressed Gases

2.12.1 The hazards of compressed gases

The hazards associated with gases can be related to the gas itself (Table 1) or the container the gas comes in. Compressed gases are supplied in steel or aluminum cylinders ranging from full size cylinders (5 ft tall) to small lecture bottles. The primary risks of gas cylinders are:

- health risks due to the gas inside (corrosive, toxic)
- risk of fire or explosion due to the gas being flammable
- the risk of explosion or rupture due to damage to the cylinder
- the risk of explosion or rupture due to heating of the cylinder (especially if the "gas" inside is actually a liquid due to compression – e.g. CO2, NH3, propane, SO2)
- the risk of a cylinder falling over and crushing feet (a full argon cylinder weighs 177 lb)
- the risk of a cylinder flying like a rocket because the valve was knocked off
- the risk of asphyxiation due to oxygen depletion in the room if the gas escapes from the cylinder.
- the risk of combustion supported by oxidizing gases. Never use oil or grease in the lines, joints or regulator.

Flammable gases can form explosive mixtures with air, but only if the gas/air mixture is inside the explosive range (see Figure 7). The explosive range lies between the lower explosive limit (LEL) and the upper explosive limit (UEL). A flammable gas with a narrow explosive range is preferred over one with a wide explosive range.

Do not use flames to detect leaks of flammable gases.

In addition to the information presented here, the Dept. of Environmental Health and Safety has a standard operating procedure document for compressed gases.

https://safety.queensu.ca/sites/webpublish.queensu.ca.ehswww/files/files/Policies%20and%20SOP's/Compressed%20Gas%20Cylinder%20Storage%20and%20Transport%20SOP.pdf

Table 1. Common gases in the laboratory.

Gas	Boiling point at 1 bar_a, ˚C	State inside cylinder	Expansion ratio	Vapour pressure at 21˚C (bar_a)*	Risks other than asphyxiation
H_2	-252.9	Gas	-	-	Flammable
O_2	-183.0	Gas	-	-	Oxidizer
Ar	-185.8	Gas	-	-	
N_2	-195.8	Gas	-	-	
CO	-191.5	Gas	-	-	Flammable & toxic
CH_4	-161.6	Gas	-	-	Flammable
C_2H_4	-103.7	Gas	-	-	Flammable
C_2H_6	-88.6	Liquid	424	38	Flammable
CO_2	none	Liquid	535	57	Mildly toxic
SO_2	-10	Liquid	535	2	Corrosive & toxic
NH_3	-33	Liquid	850	8	Flammable & toxic

* "bar_a" refers to absolute pressure. "bar_g" refers to gauge pressure (i.e. pressure above atmospheric).

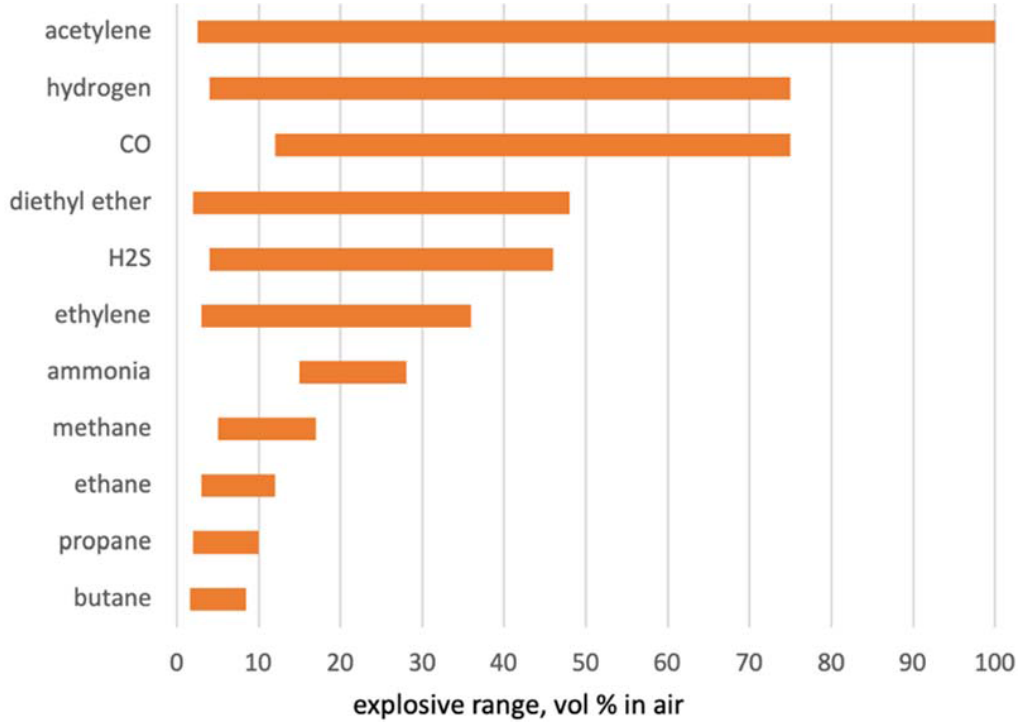


Figure 7. Explosive ranges of several gases. The orange bar is the explosive range. The left end of the bar is the LEL; to the left of this point the mixture is too lean to be explosive. The right end of the bar is the UEL; to the right of this point the mixture is too rich to be explosive.

2.12.2 Storage of gas cylinders

- Do not store or use flammable, toxic, or corrosive gases in the hallway.
- Do not store a flammable gas cylinder near open flames, sparks, flammable liquids, oxidizers or sources of ignition.
- Each gas cylinder must be restrained by its own individual chain or belt
- During storage, the cylinder cap must be in place
- Unused or partially used cylinders that are of no further use shall be returned to Chemistry Stores

2.12.3 Securing gas cylinders

- Cylinders of all sizes must be restrained from falling by restraining devices.
- Each gas cylinder must be restrained by its own individual chain or belt, except in cylinder storage racks like those at Chernoff loading dock. Rope, twine and bungie cords are unacceptable. The restraint must be at about 2/3 of the height of the cylinder.
- Place and use cylinders of toxic, corrosive, or reactive gases in a fume hood. Full size cylinders are too big and heavy to put into a fume hood, so only buy the short cylinders (half-height). Even in the fume hood, the cylinder must be secured firmly so that it cannot fall over.
- If you are using a toxic gas, buy an appropriate gas monitor/alarm and post it inside the fume hood near to the cylinder or equipment. If possible, have a second one just outside the fume hood.
- Do not expose cylinders to temperatures higher than 50°C
- Common errors with bench clamps:
    - Clamp is loose
    - Bench lip is too small
    - Strap buckle not closed properly
    - More than one cylinder per strap
    - Strap is frayed or damaged
    - Poor quality bench clamps require a screwdriver to tighten the bolts. Users are less likely to re-tighten them.

A bench clamp for securing a cylinder. There are many ways to use this incorrectly.

2.12.4 Is an oxygen or toxic gas monitor needed in your lab?

If you are using a toxic gas such as CO or H_2S, then you should have a CO or H2S gas monitor/alarm placed outside of the fume hood that contains the gas cylinder. If the gas is heavier than air, the detector should be placed lower than the fume hood opening. If the gas is the same density or lighter than air, place the monitor near the height of the worker's nose.

If your gas is nontoxic, it may be necessary to buy and install an oxygen monitor. If the volume of gas in your gas cylinder is greater than $^1/_5$ of the room volume, then you need an oxygen monitor. The calculation method differs depending on whether the gas in the cylinder is a "permanent gas" or it's liquefied by compression. Gases that have critical temperatures lower than room temperature remain gaseous even inside a full cylinder (e.g. N_2). Gases that have critical temperatures higher than room temperature are liquefied by compression (e.g. CO_2, NH_3, propane). Here are two example calculations.

EXAMPLE USING A PERMANENT GAS: A worker is planning to use an argon gas cylinder that has an internal volume of 49 L and a delivery pressure (when full) of 182 bar). The room is 36' x 36' x 10'. Is an oxygen monitor required?

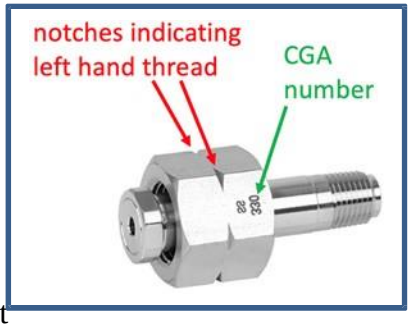
ANSWER: The room volume = 36’ x 36’ x 10’ = 12,960 ft^3 $^1/_5$ of room volume = 2,590 ft^3
$P_1V_1 = P_2V_2$ or $V_2 = P_1V_1/P_2$
volume of Ar gas after release = (182 bar x 49 L ÷ 1 bar) x 0.035 ft^3/L = 312 ft^3 Therefore vol of Ar < $^1/_5$ of room volume. An oxygen monitor is not needed.

EXAMPLE USING A LIQUEFIED GAS: A worker is planning to use a gas cylinder containing 49 L of liquid CO_2 in a 24’ x 18’ x 10’ room. Is an oxygen monitor required?
ANSWER: The room volume = 24’ x 18’ x 10’ = 4,320 ft^3 $^1/_5$ of room volume = 864 ft^3
expansion ratio for CO_2 = 535 (see Table 1)
volume of CO_2 gas = 535 x 49 L x 0.035 ft^3/L = 917 ft^3
Therefore, vol of CO_2 > $^1/_5$ of room volume. An oxygen monitor is needed!

2.12.5 Handling and transporting gas cylinders

- During transport, the cylinder cap must be in place
- Moving a cylinder more than 2 metres must be done using a cart designed for cylinder transport
- The cart should have 4, not 2, wheels
- Empty cylinders shall have the regulators removed, be marked MT, the shipping cap replaced and returned to Chemistry Stores
- Do not identify the contents by the colour of the cylinder. Use the label. If the label is falling off, secure the label properly or return the cylinder
- Be aware that special handling procedures are required for certain gases, e.g. acetylene
- If the cylinder needs to be moved then first you must:
    - disconnect regulator from the cylinder
    - replace cylinder cap

2.12.6 Attaching a regulator



1. Check that the cylinder is well secured.
2. Remove the cylinder cap.
3. Check that you have the appropriate regulator for the type of gas. The CGA number on the gas cylinder and that on the regulator should be the same. If they’re not, they won’t fit. Don’t use an adapter.
4. Find out if the regulator fitting needs a washer. If the contact surface is curved, it doesn’t need a washer. If the contact surface is flat, it may need a washer. Teflon washers are used with CGA 110, 170, 180, 320, 330, 660, 670, and 705. Replacement washers can be purchased from gas suppliers.
5. Check the threads on the regulator and the cylinder to ensure that they are free of grease, oil, dust, contaminants, or Teflon tape. Never use lubricant or Teflon tape on a regulator!
6. Holding the regulator so that the gauges are visible, thread the nut into the socket. If rotating the nut seems difficult, then stop and reinspect to see what the problem is. Note that if the nut has notches on it (see photo), then it is a left-hand thread and needs to be rotated in the opposite direction from normal.
7. Lightly tighten with a wrench. Don’t overtighten!
8. Loosen (back off) the pressure adjusting knob so that the outlet pressure will be zero.

9. Stand so that the cylinder is between you and the regulator. Open the cylinder valve slowly.
10. Set the pressure adjustment knob to the desired outlet pressure.
11. Check for leaks using an approved leak test solution that is compatible with O_2. Don't use soap solution.

If you plan to flow gas into a solution in which the gas is soluble, use a trap to prevent back-siphoning of the solution into the regulator.

After you've finished with the gas supply for a while, close the cylinder valve and then reduce the outlet (delivery) pressure to zero by loosening the pressure adjustment knob and venting the line.

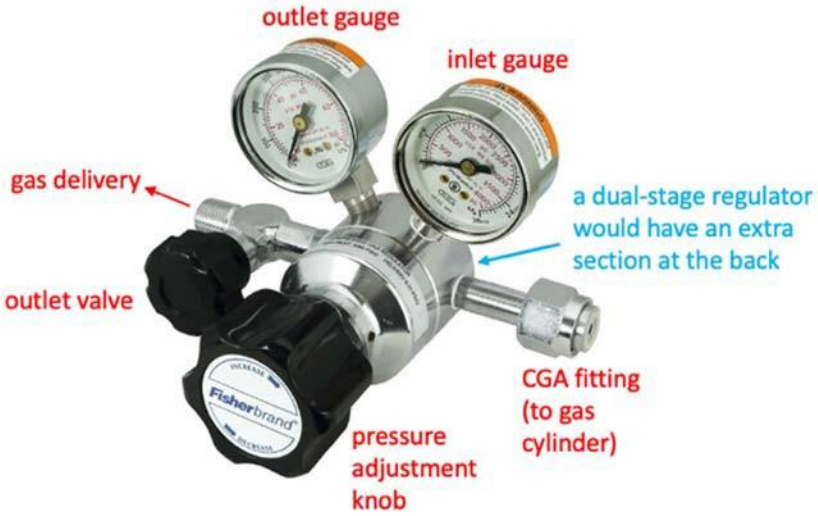


Figure 8. The key parts of a single-stage regulator (photo from Fisher Scientific).

2.12.7 To disconnect a regulator

- shut cylinder valve
- release pressure from lines
- back off the pressure adjusting knob

2.13 Harmful Mixtures

Some chemicals that can be safely handled (with appropriate precautions) on their own can be quite dangerous when mixed with another chemical. If you really need to use such mixtures, make sure you discuss it with your supervisor and agree upon a written safety protocol that will be followed. Don't be afraid to seek advice while preparing or evaluating that protocol.

a) Chemical mixtures that make acutely toxic vapours: Bleach and ammonia, or bleach and ammonium hydroxide. The gaseous products from the reaction are acutely toxic.
b) Chemical mixtures that form neurotoxic vapours: Acetone and hexane are not strong neurotoxins on their own but together are powerfully neurotoxic. If you really need to use both on the same day, then take extra precautions to avoid exposure.
c) Chemical mixtures that form explosives: Bleach and organics; hydrogen peroxide and acetone; hydrogen peroxide and sulfuric acid ("Piranha solution"); hydrogen peroxide and aqua regia (HCl and HNO_3).

2.14 Biohazards

Biohazards include infectious agents (e.g. bacteria, viruses, fungi, parasites, prions) or materials that might contain infectious agents (e.g. tissues or cell lines).

The University Biohazards Committee and the Department of Environmental Health and Safety, on behalf of the University, will determine the nature of biohazardous work in progress or proposed, accredit the facilities on an ongoing basis, assist the design of appropriate laboratories and training of personnel, and serve as an educational resource to members of the University community. The University is required to follow the Canadian Biosafety Guidelines, whether or not the work is externally funded and whether or not the sponsoring agency requires such certification.

Members of the University community who are contemplating, or who are presently engaged in work which might fall within these Guidelines are required to contact the Biosafety Officer in the Department of Environmental Health and Safety if they have not already done so.

More information is available at the Department of Environmental Health and Safety website for biosafety. https://safety.queensu.ca/biosafety

3. PHYSICAL HAZARDS

3.1. Slips, Trips, Falls, and Blocked Pathways

Avoid slips, trips, and falls by the following good practices;

3.1.1. Clean up spills as soon as possible.
3.1.2. Keep the floor clear of obstructions such as electrical cords.
3.1.3. Do not use the floor as an area for storage.
3.1.4. To reach high objects, use a proper step stool or ladder. If you will be using a stepstool or ladder, take the ladder safety training available from EH&S.

Maintain a clear and tidy floor.

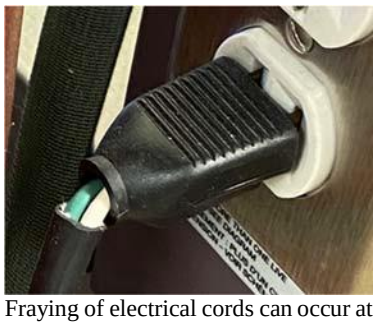
Which of these two is a better support to reach high objects?

The path to the exit from any point in a room must be 3 ft wide and free of any obstructions.

3.2. Electrical Equipment

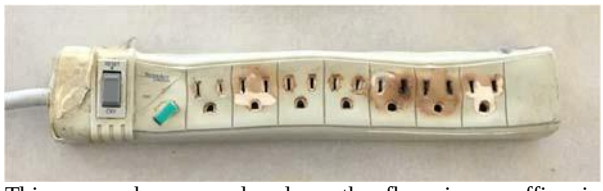
In addition to the hazards posed by electrical shock, electrical equipment also presents a source of fire hazard when used in conjunction with flammable substances (see section on **Flammability**). Electrical hazards can be minimized by the following:

- only trained or qualified individuals should repair or modify electrical equipment
- electric wires should never be used as supports
- unplug equipment by pulling on the plug not the cord
- equipment should be regularly inspected and frayed cords or broken plugs should be repaired
- any equipment failure or overheating should be remedied immediately
- use "C" class fire extinguishers for electrical fires



Fraying of electrical cords can occur at the plug or at the back of the instrument.

- Never use more than one extension cord or power bar in series.
- Power bars should not be placed on the floor. If a flood occurs, a fire could result.
- Ensure that all electrical equipment is certified by a recognized certification agency.



This power bar was placed on the floor in an office in Chernoff. A water spill caused flames to spray upwards into the bottom of a desk.

For more information, see the Standard Operating Procedure (SOP) for Electrical Equipment Certification on the EH&S website. https://safety.queensu.ca/policies-and-standard-operating-procedures

3.3.UV Lamps

Radiation of wavelengths below 250 nm poses a considerable risk to both eyes and exposed skin. Wear UV-absorbing safety glasses and avoid direct eye contact with the UV source; wear protective clothing to prevent burns from UV exposure. Work involving UV irradiation should be carried out in an enclosed work area to prevent exposure of workers to the UV source.

Mercury arc lamps should be cleaned thoroughly before use. Handling with bare hands leaves oil deposits on the surface of the outer glass which form residues that will burn into the glass causing buildup of heat during the operation of the lamp. The lamp may overheat and crack, releasing mercury vapour as a consequence.

3.4.Lasers

The Department of Environmental Health and Safety runs a "Laser Safety Program". All personnel working in proximity to Class 3b or Class 4 lasers must complete this program before starting work with lasers.

The type and intensity of radiation available from a laser varies greatly from one instrument to another. The following general rules should be followed:

3.4.1. always wear goggles that offer protection against the specific wavelength(s) of the laser in use; no available goggles protect against all laser wavelengths

3.4.2. never look directly at the beam or pump source

3.4.3. never view the beam pattern directly; use an image converter or other safe, indirect means

3.4.4. do not allow objects that cause reflections to be present in or along the beam

3.4.5. keep a high general illumination level in areas where lasers are in operation; low levels of light cause dilation of the pupils, thereby increasing the danger to the eyes

3.4.6. display warning signs

For more information on laser safety, see the Standard Operating Procedure (SOP) for laser safety on the EH&S website. https://safety.queensu.ca/policies-and-standard-operating-procedures

A useful reference document for guidance in laser safety is the "*American National Standard for Safe Use of Lasers: Z136.1 – 2014*".

3.5.Radiation Safety and X-ray Generators

The Principal of Queen's University has appointed the University Radiation Safety Committee to carry the advisory responsibility for the overall operation of the University Radiation Safety Program. The details are included in the Terms of Reference of the Committee. It is the policy of Queen's University that all activities involving ionizing radiation or radiation emitting devices be conducted so as to keep hazards from radiation to a minimum. Persons involved in these activities are expected to comply fully with the requirements of the University's License issued by the Canadian Nuclear Safety

Commission under the Atomic Energy Control Act and its regulations, as well as the Occupational Health and Safety Act and its regulations. The Radiation Safety Policy and Procedures are available through the Department of Environmental Health and Safety. https://safety.queensu.ca/policies-and-standard-operating-procedures

X-rays are a hazardous physical agent under the Occupational Health and Safety Act. Any equipment generating X-rays must be operated and registered in accordance with provincial regulations and appropriate warning signs must be posted.

3.6.Magnetic Fields

NMR spectrometers have superconducting magnets which generate static magnetic fields with high flux densities. Hazards exist from the mechanical forces exerted by these magnetic fields on ferromagnetic tools and equipment and on medical implant devices. Individuals with implanted cardiac pacemakers and similar medical devices should not be exposed to these magnetic fields. Other implanted medical devices such as suture staples, aneurysm clips, prostheses, etc. may also be subjected to adverse effects.

In the NMR lab, yellow/black chains indicate where the 5-gauss line resides around the magnet: 5-gauss (G; or 0.5 millitesla) is considered safe for most situations. Items such as watches, cameras may be magnetized and irreparably damaged if exposed to fields above 10 G. Information encoded magnetically on credit cards may be irreversibly corrupted. Please leave these items on the table with the computer. The computers are all outside the 5 G line. All magnetic objects should be kept outside of the 5 G line. This includes keys, wallets, mechanical watches, tools, gas cylinders, etc. ***Assume that any piece of metal is magnetic until proven otherwise***.

3.7.Reduced Pressure Operations and Vacuum Pumps

3.7.1. vacuum desiccators should be taped or encased due to the risk of implosion

3.7.2. glass vacuum lines should be shielded when in use

3.7.3. cold traps should be placed between apparatus and vacuum pumps to prevent volatiles from entering the pump oil; traps should be cleaned after use

3.7.4. exhaust from pumps should be vented into a ventilation control system, not into the open lab; this includes venting of PIAB compressed air vacuum apparatus

3.7.5. pump belt drives must have a guard over the belt to prevent anything from getting caught in the belt

3.7.6. if there is sound insulation near a pump, check that it's not readily combustible. See section 3.11.

3.8.Microwaves

Microwave radiation is a potentially harmful physical agent. The following general points should be noted when using microwave sources:

3.8.1. do not attempt to use microwave ovens with the door open

3.8.2. do not use metal containers in microwave oven

3.8.3. ensure that seals around doors are clean and undamaged

3.8.4. microwave equipment should only be modified or repaired by qualified personnel

3.8.5. microwaves should be used for either chemistry or for food and not for both. Label the microwave either "Food Only" or "Caution No Food Allowed". Such stickers are available from EH&S.

3.9.Excessive Heat

The Environmental Health and Safety (EH&S) document, *Working in Hot Environments* (SOP-

Safety-01), shall be the policy of the Department of Chemistry and its procedures will be followed in the event of extreme high temperatures. This policy is most likely to come into effect in the event of a failure of the air conditioning system in Chernoff Hall. The EH&S SOP does not explicitly address hazards posed by extreme high temperature in the laboratory setting and leaves it up to individual departments to establish operational protocols.

In the event of extreme high temperatures (~30 ˚C), personnel in the Department of Chemistry will be required to do the following:

1. Remove from the open lab all solvents or liquids with low flash points (Class 1A, e.g. diethyl ether, ethylene oxide, pentane, triethylamine) and store in solvent cabinets.
2. All experiments or reactions using solvents that have low flash points should be shut down, and not resumed until safe to do so.
3. All other temperature and moisture sensitive materials should be safely stored.
4. All non-essential heat producing equipment should be turned off, if safe to do so.
5. Any individuals affected by heat stress should be treated in accordance with other Medical Emergencies (**section 3.5**).

3.10.Ergonomics and other Office Hazards

While injuries due to chemical exposure and fires may get more attention, many injuries can come from much more mundane activities like sitting at a desk. To avoid repetitive strain injuries, make sure that your body position is as described in the following guidelines.

3.10.1. Your feet should be flat on the floor or a footrest.

3.10.2. Your knees should be further forward than, and clear of, the front edge of the chair

3.10.3. Your upper legs should be horizontal

3.10.4. The back of the chair should support your lower back.

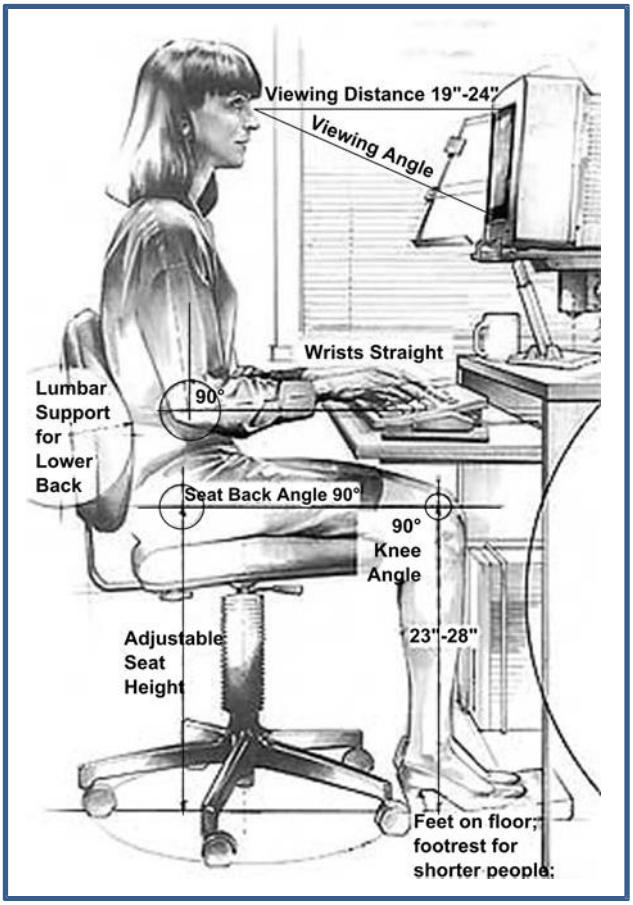
3.10.5. Your torso should be vertical.

3.10.6. Your forearms should be horizontal and your wrists straight.

3.10.7. Your shoulders should be relaxed and square-on to the computer monitor.

3.10.8. Your head should be above, not forward of, your torso.

3.10.9. Your eyes should be at the same height as the top of the monitor. For more information, see the EH&S Ergonomics website. https://safety.queensu.ca/general-safety/ergonomics



Here are some other dangerous things to watch out for in offices.

- Tripping hazards such as wires, garbage, or other items on the floor
- Tipping hazards such as wall units that aren't anchored to the wall
- High-up hard-to-reach items that are usually accessed by standing on a chair or desk. Move the item or get a ladder or step-stool.
- Chairs having damaged or faulty wheels or mechanisms. Get them repaired!
- Space heaters near combustible items such as paper or curtains.

- Chemical samples or containers that aren't properly labelled
- Frayed or damaged electrical cords.
- Cluttered or narrow exit route.

3.11. Combustible Materials

3.11.1. Do not allow combustible materials to pile up in a lab, hallway, or near the exit route within any room.

3.11.2. Do not store combustible materials such as marked exams in the hallway.

3.11.3. Do not use readily combustible sound-proofing insulation in a lab or near a heat source. If you want to find out whether the insulation is readily combustible, tear off a small piece and, in an otherwise empty fume hood, hold it with a clamp or long tongs and touch it with a flame. See photos.

Don't use combustible sound-proofing insulation in a lab

Don't allow combustible material to pile up, especially near an exit to the room

4. LAB PROCEDURES AND TECHNIQUES

4.1. Working Alone

Undergraduate students must not work alone in a laboratory at any time. A second person (not another undergraduate) must be present and must assume responsibility for supervision of the undergraduate. The work carried out must be authorized by a faculty member.

For other members of the Department, working alone is usually defined as working in a laboratory outside of normal working hours (8 a.m. to 6 p.m., Monday through Friday) in the absence of any other co-workers. Individuals may work alone if their laboratory work is of a non-hazardous nature and if there is someone else working on the same floor of the building.

If, for some reason, hazardous work must be performed outside normal working hours then the following procedure must be followed:

1. The work must have your supervisor's approval,
2. A second co-worker must be available in case of emergency, or
3. Use the "Work Alone" feature on the SeQure app. It will set up automated monitoring. If you fail to respond within 5 min when prompted by the app, the emergency contact will be called. Alternatively, if you don't have a smart phone, call the Emergency Report Centre at 613-533-6080 (or extension 36080) to inform them of where you are working, how long you will be there, and the phone number of the closest phone; they must be contacted once your work is completed. For details, see this website: https://www.queensu.ca/security/services/lone-worker-program

If you are working late at night, both the Campus Security Safe Walk Service (36080) and the A.M.S. Walk-home Service (39255) are available.

4.2. Overnight Experiments

Experiments left unattended overnight must have a notice posted nearby. Use the After-Hours Experiment Form available on the department's safety website. Put it in a transparent folder adjacent to the fume hood. Security will then know what's going on and whom to call if a problem occurs.

4.3. Off-Campus Activities

Queen's University has an Off-Campus Activity Safety Policy that is designed to assess risk associated with various off-campus activities such as field work, trips associated with courses, international travel and many other situations. Note that in many instances this risk assessment is **mandatory** before an off-campus activity can be carried out. The full policy document is available through the University Secretariat website or the EH&S website.
https://www.queensu.ca/secretariat/policies/board-policies/campus-activity-safety-policy

4.4. Chemical Storage

Stored chemicals must be segregated by type, so that bottle breakage or leakage will not lead to the mixing of incompatible chemicals. While there are extensive resources online about chemical incompatibility, most problems of this type can be avoided by storing chemicals in the groups shown in Figure 9. Note that this chart does not include materials less commonly found in a chemistry lab, such as biohazards, radioactive materials, or explosives.

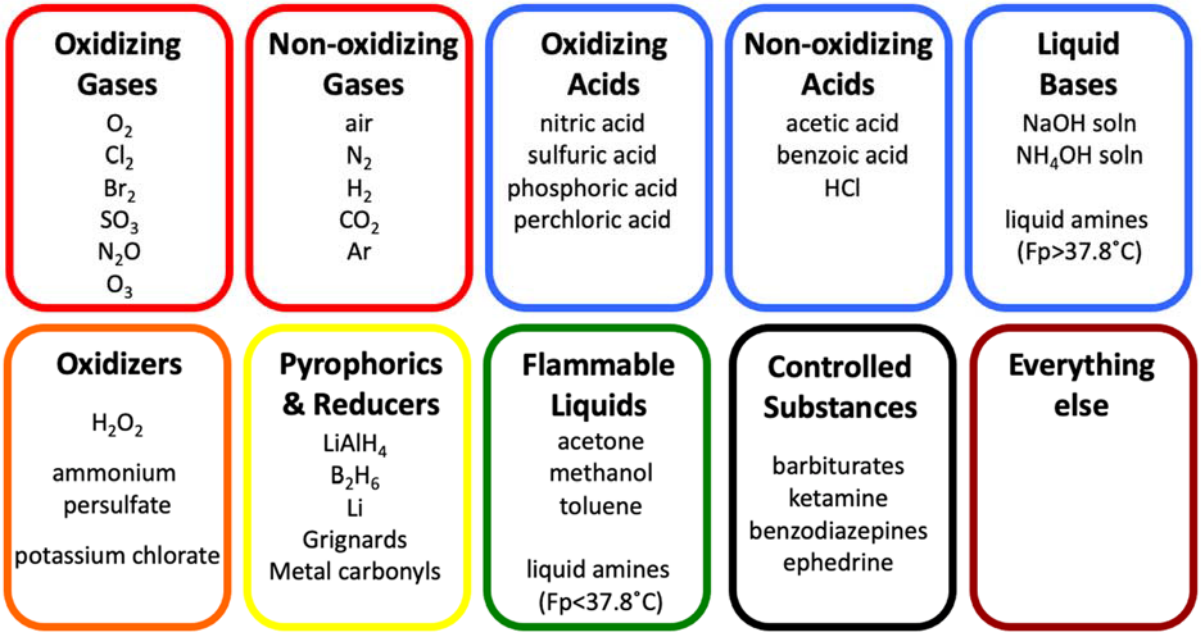


Figure 9. Ten classes of chemicals. If stored chemicals are segregated into these ten classes, most problems of chemical incompatibility can be avoided. Note that this chart does not include materials less commonly found in a chemistry lab, such as biohazards, radioactive materials, or explosives.

Do not:

4.4.1. overcrowd shelving or cabinets
4.4.2. store chemicals on the ground
4.4.3. store chemicals in fume hoods (they will impede airflow)
4.4.4. store chemicals near exits, heaters, ovens, under sinks, or in direct sunlight.
4.4.5. store controlled substances in unlocked locations
4.4.6. allow labels to degrade or fall off (fix or replace them before they are lost)

Refrigerators and freezers may also be used to store chemicals, provided that:

4.4.7. The fridge or freezer is labeled "Caution: No Food"
4.4.8. If flammable or combustible liquids will be stored inside, the fridge or freezer must be explosion-proof and labeled as such. Conventional fridges modified to move the electrical controls to the outside are not allowed.

As part of a periodic lab clean-up, go through your chemical storage locations to look for bottles that are damaged or leaking, or have damaged or decaying labels (Figure 10).

For more information about chemical storage, see the Standard Operating Procedure available from EH&S.
https://safety.queensu.ca/sites/webpublish.queensu.ca.ehswww/files/files/Policies%20and%20SOP's/SOP-Chem-05-chemical%20storage%20procedures(1).pdf

Figure 10. Problematic bottles having a damaged label or leaking caps.

4.5. Glassware

4.5.1. Handling Laboratory Glassware

In general glassware used for standard laboratory procedures is made of borosilicate glass. Prior to carrying out an experiment the following should be done:

- check glassware for cracks, chips and other flaws; these flaws should be repaired before the glassware is used
- select the right glassware for the job: vacuum applications required thick-walled glass while operations carried out under pressure require specially designed glassware
- glassware under pressure or vacuum should be shielded
- if it is necessary to apply pressure to glassware, wear thick leather gloves
- never heat or apply pressure/vacuum to a chemical in a stock bottle; these bottles are made of a soft glass which breaks readily.

Cuts by broken glass are the second most common injury in our department. Here are some tips that will help you avoid such injuries.

- Never use glass objects to apply pressure to anything. Don't use a glass object as a scraper, a press, or a lever.
- Discard broken glassware or get it repaired.
- When pushing a glass fitting into a pre-holed rubber stopper or rubber tubing, use glycerol to lubricate it and wear cut-resistant gloves (see photo from Fisher).
- Glassware that will contain a vacuum (vacuum flasks, Dewars, desiccators) should be wrapped in "poly-net" or taped with fibre-reinforced friction tape in a crisscross pattern so that shards of glass don't fly if the flask should implode.

4.5.2. Cleaning Laboratory Glassware

For most cleaning applications, laboratory glassware is soaked in an aqueous detergent solution (e.g. Sparkleen®, Alconox®) followed by rinsing with de-ionized water and drying. In some situations, more chemically aggressive cleaning solutions are employed; listed below are some of the more commonly encountered cleaning solutions, with the associated hazards:

- Alcohol/base baths: typically, 50% aqueous base in an alcohol solution. Removes silicone grease as well as many organic residues. Highly corrosive to skin and eyes, therefore requires appropriate personal protection. Prolonged exposure of glassware to strong base leads to etching, particularly to ground glass joints, and readily destroys sintered glass funnels. The base bath represents a very large volume of flammable liquids and must therefore be stored in a flammable's cabinet.

A flammables cabinet suitable for cleaning baths that contain flammable solvents.

  Appropriate cabinets for such wash baths are available (see photo).
- Acid/oxidizer baths: Historically, **chromic acid** has been used as an oxidizing cleaner however disposal of chromium waste is now problematic; this cleaning solution is no longer recommended! **Ammonium persulfate/sulfuric acid** has been used as a metal-free cleaning solution, as has **nitric acid** either alone, or in conjunction with other acids (hydrochloric or sulfuric acid). Aqua regia (HCl/HNO_3 mix) is often used to clean up deposited transition metal residues. **Piranha solution** (hydrogen peroxide and sulfuric acid) has been used in the semi-conductor industry but it, like many other acid/oxidizers, is known to react violently if mixed with significant quantities of organic solvents (e.g. acetone). As a consequence of the hazards associated with the use of acid/oxidizer baths, **they can only be used with approval of your supervisor and with a mutually agreed- upon safety plan.** That plan should include, but not be limited to, the following points:

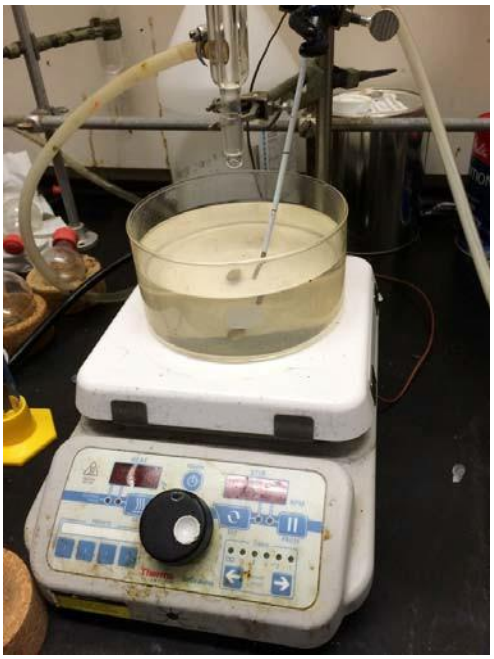
  - Make only as much aqua regia or piranha solution as is immediately required.
  - To make aqua regia, add HNO_3 to HCl. Never the reverse!
  - Neutralize aqua regia very slowly with $NaHCO_3$ solution
  - To make Piranha solution, add peroxide very slowly to H_2SO_4. Never the reverse!
  - dilute Piranha solution tenfold with water (by adding it to water) before sending for disposal
  - prepare a written safety protocol that you and your supervisor agree with.
  - put a blast shield or sash between you and the solution
  - don't remove them from the fume hood
  - never contact the mixture with organics!
  - never cap the container. It may overpressurize.

4.6 Hot Plates

Hot plates have caused at least one recent lab fire at Queen's. In order to avoid further fires, please follow these best practices (thanks to the University of Illinois for these suggestions):

- Don't heat flammable liquids with a hot plate.

- If it has a probe, ensure that the probe is secured in the sample or oil bath and cannot fall out.
- Unplug the hotplate when it's not in use. Simply switching it off is insufficient. Older or damaged hotplates may heat up even when they're switched off.
- Throw away any hotplate that has been damaged (e.g. liquids got into the electronics) or are older than 1984.
- If you only need stirring, not heating, then don't use a hotplate. Use a stirrer.
- Periodically test the function of the off switch to verify that it works and the heating device quickly cools. If the device fails the test, take it out of service immediately.
- When buying a new hotplate, select one that is hermetically sealed to protect electronics from liquids and gases
- Look for two independent temperature control circuits that shut off power when the temperature exceeds a selected limit.



Many hot plates use a probe to monitor the temperature of the heating bath. If the probe falls out, overheating can result.

4.7 Cold Traps

Cold traps are used to protect a vacuum pump from organic vapours, typically when the vacuum pump is connected to a rotary evaporator or a vacuum manifold. A cold trap is surrounded by a coolant such as acetone/dry ice or liquid nitrogen, and therefore condenses any organic vapours coming from the evaporator or manifold. If organic vapours are allowed to reach the vacuum pump, the result will be, at minimum, corrosion of the rubber seals inside the pump, and, at worst, explosion and fire.

A pump that was not protected from organic vapours. https://ehrs.upenn.edu/health-safety/lab-safety/safety-alerts-and-faqs/vacuum-pump-explosion-chemistry-building

However, cold traps pose risks of their own. The most serious risk is that of an overpressurization explosion after liquid oxygen or liquid argon has been condensed inside the trap. This is what happens: during use, air or argon is inadvertently allowed to pass into the cold trap and condenses to liquid O2 or Ar inside the trap (see figure at right). The boiling points of O2 and Ar are slightly higher than that of liquid N2 (see Table 2). Liquid O2 is a lovely blue colour. Later, when the trap is no longer needed, the operator will remove the liquid N2 coolant. Very shortly thereafter the condensed liquid will gasify and, if it cannot find a path out of the glassware, will cause an overpressurization explosion. There is also the possibility that liquid O2 might react with organics caught in the trap.

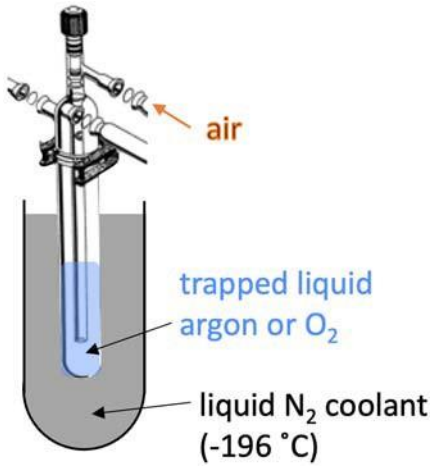
What to do if you see blue in a liqN_2 cold trap?

1. Do not turn off the pump or remove the liqN_2.
2. Place a blast shield in front of the trap.

3. Evacuate the immediate area and **seek help.**
4. If help is unavailable, then keep the pump on and allow the trap to slowly warm up as the liquid nitrogen evaporates. Don't add more liqN_2.

How to disconnect a liqN_2 cold trap (assuming you haven't seen any blue colour):

1. Turn off the pump
2. **Simultaneously** remove the liqN_2 dewar AND open a vent to air.
3. If you see liquid in the trap, evacuate the area while the trap warms up.



It's easy but quite dangerous to trap liquid O_2 or argon in a liquid nitrogen-cooled trap.

Table 2. Properties of cryogenic liquids.

Gas	Boiling point at 1 bar_a, ˚C	Expansion ratio	Risks other than frostbite
O_2	-183.0	843	Oxidizer, supports combustion, overpressurization
Ar	-185.8	824	Asphyxiation, overpressurization
N_2	-195.8	682	Asphyxiation, overpressurization

* "bar_a" refers to absolute pressure. "bar_g" refers to gauge pressure (i.e. pressure above atmospheric).

Coolants that maintain a temperature above -180 ˚C cannot condense liquid O_2 or liquid Ar, but have other risks instead (Table 2). When choosing a coolant, consider all risks and the temperature required to trap the expected organic vapours. If using a mixture of acetone (or other organic liquid) and dry ice, add the acetone to the dry ice, not the other way around.

Table 3. Common coolants and their hazards (other than frostbite)

Coolant	Temperature	Hazards
ice/water	0 ˚C	electrically conductive
ice/NaCl	-20 ˚C	electrically conductive
acetonitrile/dry ice	-41 ˚C	flammable, harmful if inhaled
acetone/dry ice	-78 ˚C	Flammable
liqN_2/toluene	-95 ˚C	Flammable
liqN_2/n-propanol	-127 ˚C	Flammable
liquid nitrogen	-196 ˚C	may condense Ar or O_2

4.8 Distillation and Reflux

Distillations and reflux operations are common laboratory procedures which present several potential dangers: pressure buildup leading to explosions if closed systems are used, and fire hazards associated with heating flammable substances are two of the most common. A variety of apparatus designs are available to accomplish reflux/distillation operations at atmospheric pressure, under inert atmospheres, under reduced pressure and by the addition of steam. The following general points should be noted when carrying out these operations:

- check the integrity of the system; leaks of flammable materials can lead to fires
- ensure smooth boiling through stirring or the addition of boiling stones (do not add boiling stones to hot liquid)
- choose an appropriate heat source - electric heating mantle, ceramic cavity heater, steam bath or silicone oil bath
- do not heat the heat source above the autoignition temperature of the liquid being distilled/refluxed (Table 4)
- do not distill organic liquids to dryness

Table 4. Common solvents and their flash points and autoignition temperatures*

Solvent	Flash point	Autoignition temperature
acetone	-17 ˚C	465 ˚C
acetonitrile	13 ˚C	525 ˚C
anisole	41 ˚C	475 ˚C
carbon disulfide	-30 ˚C	90 ˚C
cyclohexane	-18 ˚C	245 ˚C
diethyl ether	-40 ˚C	180 ˚C
dimethyl sulfoxide	88 ˚C	215 ˚C
ethyl acetate	-3 ˚C	410 ˚C
ethanol	12 ˚C	363 ˚C
n-hexane	-26 ˚C	223 ˚C
isopropanol	12 ˚C	399 ˚C
methanol	11 ˚C	464 ˚C
n-pentane	-49 ˚C	260 ˚C
tetrahydrofuran	-17 ˚C	321 ˚C
toluene	4 ˚C	480 ˚C

* An autoignition temperature is the lowest temperature at which the vapour will ignite without a spark or flame being present.

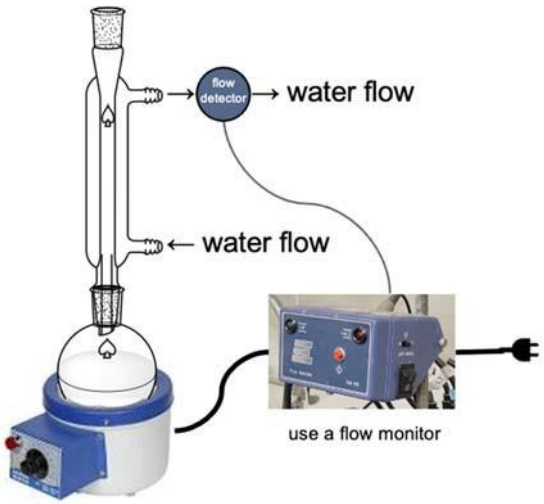
The Department has standard operating procedures for the distillation and reflux of flammable liquids at atmospheric pressure in fume hoods:

1. The following items must be checked prior to carrying out a distillation or reflux operation:
   a) all heating mantles must be inspected for defects; discard any defective equipment
   b) all power cords must be inspected for defects; defects must be repaired prior to use
   c) all glassware must be inspected for integrity, securely assemble and properly clamped
   d) all water hoses must be securely attached with the approved clamps obtainable from Science Stores; all water leads to drains must be secured (a clamp or weight holding the free end in the sink); water flow must be confirmed

e) any possibility of pressure build up in the glassware must be avoided; do not heat a closed system
f) appropriate measures (boiling chips or stirring) must be taken to avoid bumping
g) all reflux operations must have written identification if they are to be left unattended
h) electrical devices that have the potential to generate arcs or sparks, other than stirrers required to prevent bumping, shall not be operated in the fume hood during reflux/distillation operations

2. No flammable liquids or flammable compressed gases shall be stored in fume hoods during a reflux/distillation operation
3. Written identification must include the following:
   a) identification of the flammable solvent
   b) relevant physical properties including melting point, boiling point, autoignition point and flash point
   c) operator's name and contact number
   d) supervisor's name and contact number
   e) any additional relevant information
4. General procedural guideline:
   a) the maximum total volume of flammable liquids that may be distilled/refluxed in an individual fume hood at one time will be 6 litres
   b) distillations shall not be left unattended; reflux operations may be left unattended/overnight with the appropriate identification
   c) hood sashes shall always be lowered when manipulations are not in progress and shall be used as shields when manipulations are carried out
   d) the temperature of the heating mantle must be well below the autoignition temperature of the solvent being
   e) distilled/refluxed; a recommended limit is 80% of the autoignition temperature.
5. Authorization for the use of procedures which deviate from the above rules must be obtained from the Department Safety Officer.

A water flow monitor is a safety device that continuously monitors the flow exiting the condenser. If the water flow falls to low or stops, then the flow monitor cuts of the power to the heating mantle. Such flow monitors are highly recommended. An example model is the Electrothermal FM110.



A water flow monitor will cut off the power to your heating mantle if the water flowing out of your condenser gets too slow or stops.

Using a distillation apparatus to dry solvents (i.e. remove trace water) is neither the safest nor the most effective approach. Using a solvent purification apparatus that passes the solvent through a bed of alumina is more effective at removing water to low levels (*J. Org. Chem.* 2010, 75, 8351) and is safer too!

4.9 Freeze-pump-thaw degassing

This is a common method for removing air from solvents. However, if done incorrectly, there can be a devastating accident. If you accidentally condense liquid oxygen or liquid

argon into the solvent flask when it's cold, the flask could explode when it's warmed up. The shards of broken glass will fly like bullets, breaking or cutting through glass, plastic, or flesh. Even the fume hood sash isn't strong enough to withstand such an accident. Follow these tips when freeze-pump-thaw degassing a liquid:

- always have a blast shield between the flask and yourself
- use a round-bottom flask, not a cylindrical Schlenk tube
- never fill the flask more than half-way with solvent
- the hose between your flask and the gas/vacuum manifold should contain vacuum *throughout* the procedure.
- for the detailed procedure, see these websites:

http://depts.washington.edu/eooptic/linkfiles/Freeze_Pump_Thaw.pdf
http://www.chemistryviews.org/details/education/4308331/Tips_and_Tricks_for_the_Lab_Ai_r-Sensitive_Techniques_2.html

4.10 Syringes


A bad practice that can lead to puncture wounds

Accidentally poking yourself with a syringe needle is a potentially serious injury that may look benign at first. Even if the syringe was "empty" or only contained solvents rather than more harmful chemicals, the injury could become serious over time. If the puncture wound or the surrounding area becomes pink or purple over time, then the flesh is being destroyed by necrosis. This can happen with any solvent, although the most publicized example involved CH_2Cl_2 (Vidal, *ACS Cent. Sci.* 2020, 6, 2, 83). The cure is surgery to remove the affected flesh before the damage spreads further. If you receive a puncture wound that might have transferred even a very small amount of solvent or other material, inform a labmate or supervisor and then seek medical assessment as quickly as possible. Inform the medical staff of what chemical may have been injected. The labmate should stay with you in case you become unable to take care of yourself.

In order to avoid puncture wounds from syringes, follow these practices:

- don't leave syringes or pipettes sticking out of benches or containers
- don't point a needle towards or nearly towards your hand or body
- avoid recapping a needle.
- if you must recap it, don't hold the cap with your hand. Use the scoop technique (see photo).
- dispose of the needle only in a sharp's container.


The scoop method for capping a needle

4.11 Transporting Materials

4.11.1Transporting compressed gases or cryogens in the elevators

The north elevator in Chernoff Hall is for passengers and non-hazardous freight. No hazardous materials are permitted (e.g. solvents, samples, cryogens, gases, chemicals) unless the south elevator is out of service. The south elevator is for passengers, freight, and hazardous materials.

Never ride an elevator with a gas cylinder, dry ice, or a cryogen. If the elevator

gets stuck, you may be asphyxiated before you are rescued. For dry ice, carry it up the stairs if possible. If the amount of dry ice is too much to carry upstairs, or you are transporting a gas cylinder or a cryogen, put the container in the south elevator, pull the retractable caution tape across to block both doors, push the button corresponding to the destination floor, and then exit the elevator. A labmate should be waiting at the destination floor.

If you want to use an elevator and see the caution tape pulled across, do not enter the elevator.

4.11.2 Transporting hazardous materials on campus

- use a plastic or rubber safety carrier, even for smaller bottles. See Figure 11.
- for larger amounts, call Ben Fiegen at EH&S for assistance.

Figure 11. (left and middle) Safety carriers for transporting chemicals on campus. (At right) A portable dewar for transporting liquid nitrogen on campus.

4.11.3 Transporting hazardous materials between campuses

To transport hazardous materials between the local campuses (main campus, west campus, The Isabel, and Innovation Park), do not use your private vehicle. Call Ben Fiegen at EH&S for assistance.

4.11.4Transporting hazardous materials between Queen's University and other locations

Do not transport hazardous materials by mail, in your own vehicle, or in your luggage. Ask Science Stores for assistance and advice. University policy and advice is available at the EH&S website. https://safety.queensu.ca/policies-and-standard-operating-procedures

4.12 Undergraduate Teaching Labs

The responsibility for safety is shared by all staff and students working in undergraduate laboratories. These laboratories must be operated in a manner that is consistent with the safety procedures of the Department. The following points should be noted:

- safety goggles must be worn in the laboratories while labs are in progress
- open-toed shoes or sandals must not be worn
- long pants (without holes) and a lab coat must be worn to protect exposed skin
- long hair, including beards, must be tied back or contained by a net, cap or other device
- TAs and staff must be familiar with the experiments being carried out, must be aware of the correct procedures and must be aware of the hazards associated with those experiments
- undergraduates must not work alone in a laboratory
- TAs must ensure that all students under their supervision know where emergency

equipment is located, and what the procedures are for dealing with medical and fire emergencies

- chemicals from unlabeled containers are not to be used; unlabeled chemicals should be reported to a TA, lab technician or lab coordinator
- all work areas must be kept clean and tidy
- all accidents must be reported promptly

5. SAFETY EQUIPMENT

A variety of protective measures are available for dealing with the hazards present in the chemical laboratory. One of the simplest measures to reduce or eliminate a hazard is to substitute a less hazardous or non-hazardous material for one which presents a high level of risk. For example, many older literature procedures may use solvents such as benzene or carbon tetrachloride for routine applications; it is now known that benzene is a potent carcinogen and that carbon tetrachloride can cause serious liver damage. Substitution of these solvents with toluene or dichloromethane may pose less risk if compatible with the procedure. A second measure is to reduce the scale of an operation to reduce the level of risk.

Smaller reactions are less likely to cause serious accidents if something goes wrong; they also produce less waste.

5.1 Fume hoods

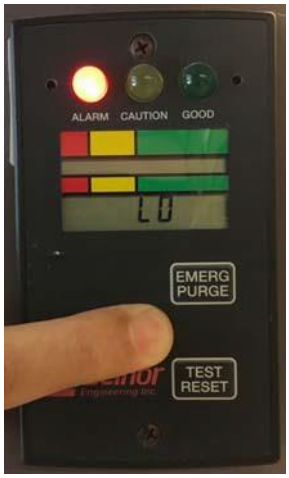
The most common method to prevent exposure to hazardous chemicals by inhalation is to work in a ventilated work space provided in a fume hood. Protection is provided by air flow through the fume hood. Annual inspection and servicing are carried out on fume hoods to ensure proper operation however it is important to note that the protection offered by a fume hood can be compromised if the sash is opened too high or if the airflow is obstructed by equipment or chemicals stored in the fume hood. Keep the following points in mind when using a fume hood:

- Keep all apparatus at least six inches from the front of the hood; airflow is less likely to be impeded and vapours are less likely to escape
- Don't use the hood to store chemicals and equipment; they restrict airflow. Only keep what you need in the fume hood.
- Raise large objects onto supports
- Cords should be fed into the fume hood under the airfoil.
- Keep the workspace tidy.
- Proper fume hood ventilation of labs requires that doors to the lab be kept closed
- When the fume hood is in use, the sash should be kept at or lower than the height indicated by the EH&S sticker, and down when it is not in use.
- Don't raise the sash quickly
- Keep the sash between you and your work.
- No unnecessary foot traffic near the fume hood.
- Don't move your arms or objects quickly in the fume hood.

A cluttered fume hood will not have good air flow.

The air flow monitor and alarm must be kept in working order. It is an offence under the *Occupational Health and Safety Act* to disable any protective device such as the airflow monitor/alarms on fume hoods. Any fume hood without a properly functioning airflow monitor/alarm must not be used. While it is possible to deactivate the alarm, don't do it.

• *Temporarily muting* the alarms is permitted. If the alarm is sounding while you temporarily need the sash wide open, hit "TEST RESET" briefly to mute the alarm. The mute symbol will appear. Do not leave the area until you've confirmed the mute symbol has disappeared.
• *Long-term muting* of the alarm is illegal. If you find that your fume hood alarm is showing the mute symbol, report it to the building manager so it can get fixed.
• *Every month or so*, check that the alarm is functioning properly. Put your finger over the central hole to block the air flow (see photo). Soon, the red light should glow, and a short time later the alarm should sound. If it doesn't sound, then the alarm air flow monitor needs to be recalibrated. Send a request to recept@chem.queensu.ca in the main office.
• The "EMERG PURGE" button is an extra feature that doesn't work with the fume hoods in Chernoff Hall.



To check that the flow alarm is working properly, cover the hole with your finger. After ~20 s, the alarm should sound.

5.2 Local Ventilation

Flexible ventilation ducts with flared openings can also be used to provide ventilation in local areas, particularly with equipment which, because of size or function, cannot be placed in a fume hood. Any equipment which releases hazardous fumes during operation must have local ventilation.

5.3 Personal Protective Equipment

5.3.1Eye and Face Protection

Eye protection must be worn in the labs when hazardous chemicals are in use. The minimum requirement for eye protection is safety glasses (or prescription glasses) fitted with side shields. Unfortunately, safety glasses do NOT provide complete protection to the eyes from spills and splashes. Where more protection is required, such as when working with corrosive substances, either safety goggles or a full-face shield must be used.

Some safety goggles are uncomfortable to wear. Choose your goggles based on comfort and performance. For a review of different safety goggles, see *Chemical &Engineering News* (2020) vol 98, issue 33.

Four types of eye protection.

Safety glasses and goggles should be marked with ANSI or CSA markings to show that they meet minimum safety standards.

ANSI Markings:
• Z87 eye protection
• D3 splash protection
• D4 or D5 dust protection

CSA Markings:

• Z94.3eye protection

Contact lenses are allowed in the lab. They have both advantages (possible brief delay of harm to cornea in a splash incident) and disadvantages (may be difficult to remove in an emergency). The liquid between the contact lens and the eye may also absorb harmful vapours from the lab air, so wearers are recommended to remove the lenses at the first sign of irritation or redness. Wearers should notify coworkers and supervisor that contact lenses are being worn. If harmful chemicals are splashed into the eye, rinse for a short time to get the bulk of the harmful chemical out of the eye, then remove the contact lens and continue flushing.

5.3.2Clothing

Appropriate clothing and shoes are part of your protective equipment. Short pants and open-toed shoes or sandals offer no protection from spills of hazardous chemicals. Shoes that cover the feet completely (front and back) and long pants or a lab coat must be worn. If you are working with flames or with flammable gases or liquids, don't wear pure synthetic fabrics; they burn very well.

Long hair, including beards, and loose or voluminous clothing, such as ties, wide sleeves, or dresses, must be restrained so that it cannot dip into chemicals or get caught in moving machinery.

5.3.3Lab coats

• Lab coats are mandatory in the labs in Chernoff and Dupuis. In Chernoff Hall, the desk portion of the labs is not included in this rule.
• Lab coats are not allowed outside of the lab rooms in Chernoff and Dupuis, and not allowed outside of the buildings on university property.
• Lab coats must be worn when transporting hazardous materials outside of the laboratory.
• Lab coats with snap closures, rather than buttons, can be removed more quickly in an emergency.

	Polyester/cotton	Cotton	Cotton with flame retardant*	Nomex
Fire resistance	✗	✗	✔	✔
Acid resistance	✔	✗	✗	✔

* Do not launder with bleach.

5.3.4 Gloves


Never touch a doorknob (or your cell phone) while wearing gloves.

Gloves are available in a variety of materials including natural rubber, neoprene, nitrile and vinyl. Each type of material is resistant to only a limited range of liquids. No single type of glove is suitable for all situations. Wearing the wrong type of glove can cause more damage by keeping chemicals in contact with your skin. Choose the glove that will best block the liquids or solvents you are using, not the solutes dissolved therein. Consult manufacturer's data before selecting the appropriate type of gloves. Searching the web for "glove compatibility chart" will help you find data on which gloves are recommended for each liquid you might want to use.
https://www.ansellpro.com/download/Ansell_7thEditionChemicalResistanceGuide.pdf
https://www.coleparmer.com/safety-glove-chemical-compatibility

Disposable "examination" **latex rubber gloves** are permeable or reactive to a variety of common chemicals and are therefore rarely suitable for wet chemistry research.

5.3.5 Respirators


A gas respirator

Respirators are designed to protect the wearer from hazardous vapours or dust. A wide variety of respirators are available and are designed to deal with different substances in various situations. Your face must be free of beards, long sideburns, or stubble.

The use of respirators requires proper selection, fitting and training which must be arranged through the Department of Environmental Health and Safety. **Do not use a respirator** unless you have been properly fitted and trained. Procedural and engineering changes should be considered in reducing the risk of exposure prior to any respirator use in a laboratory; respirators should be a last resort.

5.3.6 Hearing Protection

Routine exposure to noise in excess of 90 dB requires the use of hearing protection (i.e. ear plugs, ear muffs). For extended exposure to noise in excess of 80 dB, hearing protection is advised.

5.4 Emergency Equipment

5.4.1Eyewash Fountains and Showers

Eyewash & shower station in Chernoff Hall

Eyewash fountains and showers are located in the corridors outside research labs, and have instructions for their use posted. Access to this equipment must not be obstructed in any way. Nothing should ever be on the **green** area of floor. Don't station electrical equipment beside the shower/eyewash equipment. Additional safety showers are located in the washrooms at the end of each research corridor.

Emergency Eyewash Fountains and Showers must be regularly tested to ensure that flushing fluid is available, to clear the supply line of any sediment build-up and to minimize microbial contamination due to stagnant water.

If it is necessary to use an eyewash fountain, pull the station towards you by one of the horizontal bars. It will fold down to a horizontal position and the water flow will start automatically. Hold your eyelids open with your fingers and roll your eyes back and forth while washing them. While flushing, ask someone to contact security by calling 36111 or pushing the **RED** button on the wall. Flush your eyes for at least 15 minutes to ensure removal of the chemical, even longer if the chemical is likely or known to be harmful to the eyes. Stop when the emergency first responders arrive and tell you to stop. Be sure to seek medical attention after the incident is over.

A first-response eyewash station that can be ordered through Stores

Because most of the eyewash stations are out in the hallway, workers may wish to obtain a first-response eyewash station (see photo). Such a station contains bottles of eyewash solution that can remain in the lab and be used within a few seconds of the first contamination of the eye. Such bottles do not serve as replacements for the eyewash stations but rather as a faster first response that may be more accessible in the lab. Replace the solution every year.

If you get harmful chemicals splashed on your body, activate the shower by pulling down the black handle to the right of the eyewash station.

Remove all clothing. While showering, ask someone to contact security by calling 36111 or pushing the **RED** button on the wall. If passersby are available, one of them (preferably of the same gender) can hold up a lab coat to protect modesty, but modesty is NOT as important as removing the harmful chemical or as important as calling for help from security. After preliminary decontamination, you may proceed to a washroom to continue the showering in greater privacy. Have a colleague remain outside to direct the first responders to your location if they haven't already arrived. Be sure to seek medical attention after the incident is over.

Exceptions:

a) For a splash of phenol on skin, do not rinse it off with water. Rinse it off with liquid PEG (polyethylene glycol). Make sure you have a bottle of liquid PEG on hand if you're working with phenol.
b) For a splash of HF on skin, apply calcium gluconate gel to the skin after the initial water wash.
c) For organophosphate poisoning, consult by phone with emergency personnel before administering an antidote.
d) For most other toxic compounds, do not apply an antidote. Leave that to first responders.
e) For acid or base spills, do NOT try to neutralize the liquid on your skin. The neutralization reaction is exothermic; the resulting heat will cause thermal burns. Wash with water or diphoterine solution.

5.4.2Fire extinguishers

Figure 12 shows the most common types of fire extinguishers. All laboratories are equipped with "ABC" class fire extinguishers (Dry Chemical) which are suitable for most fires except metal fires; those labs with significant quantities of pyrophoric metals are also equipped with "D" class extinguishers. These extinguishers are only designed to fight small local fires. Do not attempt to fight large fires; evacuate the building and call for professional fire fighters (telephone 36111 - Emergency Report Center). All use of fire extinguishers must be reported to the Department Safety Officer. See Chapter 6.2 for more information about fire emergencies.

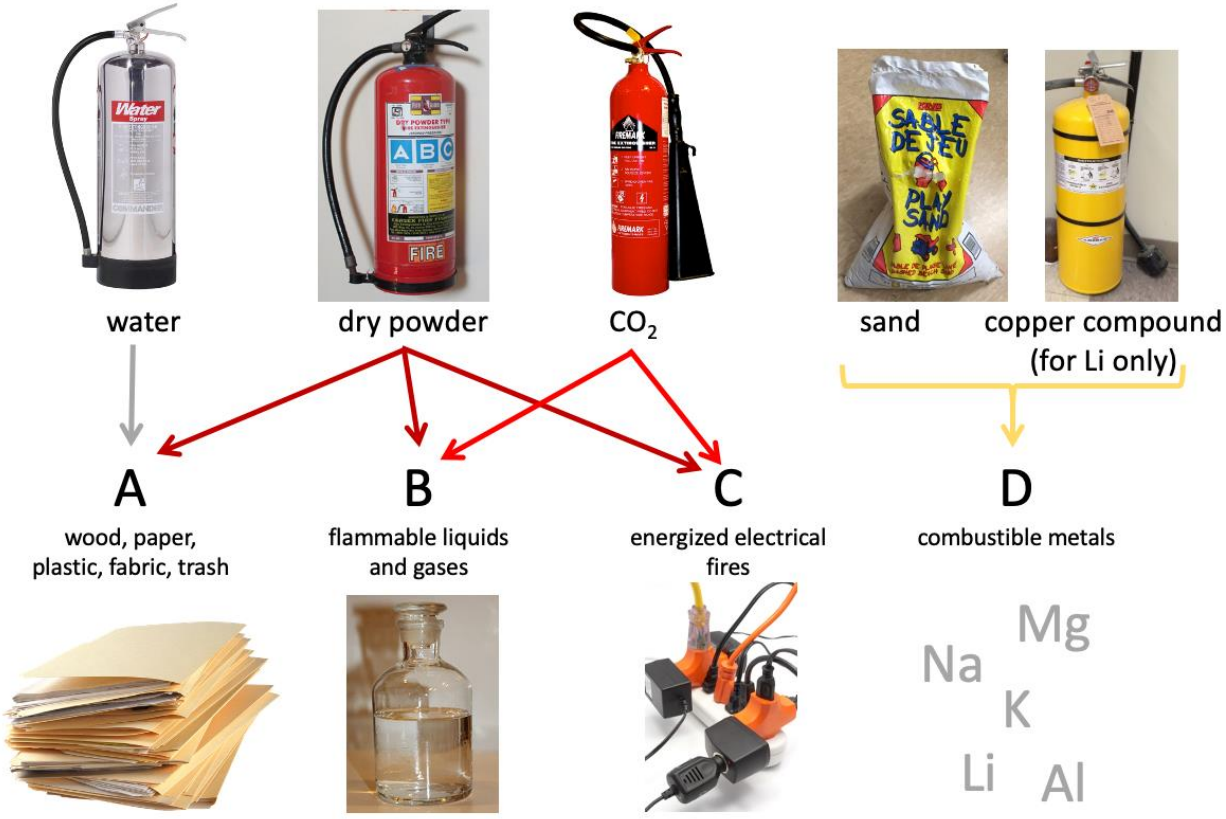


Figure 12. The four types of fires and the appropriate fire extinguishers for each type.

6. EMERGENCY PROCEDURES

Pushing the RED button calls Security, just as if you had called 36111.

In an emergency, calling 36111 or pushing the **RED** button on the wall is better than calling 911 because the response will be faster.

6.1 Medical Emergency

Minor accidents involving hazardous chemicals or the malfunction and/or breakdown of equipment must be reported to your supervisor. More serious accidents must be reported to the Head of the Department and/or the Department Safety Officer as well as to your supervisor.

All accidents involving personal injury must be reported promptly to your supervisor who is responsible for ensuring that the procedures below are followed. If your supervisor is not immediately available, contact the Department Safety Officer or the Head of the Department.

- Apply first aid (first aid kits should be available in all labs); first aid should be given by someone who has had appropriate training
- In the case of minor injuries that cannot be satisfactorily treated by first aid alone, or if there is any doubt, the injured person shall be sent or taken to the hospital emergency room, or doctor of his/her choice.
- In the case of injuries that are more severe, or there is doubt about the severity of the injury, and emergency assistance is required, call **36111** from an internal phone (or push the **RED** button or call 613-533-6111 from an external phone). A SEVERELY INJURED PERSON MUST NOT BE MOVED without the advice of medical or ambulance personnel unless there is an immediate threat such as an approaching fire or chemical spill.
- If it is necessary to call an ambulance, indicate the location of the injured person and the location of the nearest appropriate entrance to the building. If possible send someone to that entrance to lead the ambulance personnel to the injured person.

For all accidents involving critical injury or death:

- Immediately call 36111 for assistance (or push the **RED** button).
- As soon as possible, notify your supervisor, the Head of the Department (or Safety Officer), and the Department of Environmental Health and Safety. The latter will notify the appropriate government agencies.
- Do not touch anything associated with the accident, except for the purpose of saving life, relieving suffering or preventing unnecessary damage to equipment or property. The scene of an accident must be examined by the appropriate authorities

6.2 Fire Emergency

Operating a fire alarm in Chernoff Hall

You must be aware of the location and/or use of all fire extinguishers, fire alarm switches and fire exits in your area. Take fire extinguisher training at the first opportunity.

If the fire is not large, and if you are not alone, then you can try to fight the fire. Follow these steps.

1. Remove flammable and volatile chemicals in the vicinity of the fire
2. If it is an electrical fire, and IF IT IS SAFE TO DO SO, disconnect the power supply to the equipment that is on fire. If you are unable to do so, then you may still try to fight the fire but be careful not to touch the equipment even after the fire is out.
3. If it is a burning flammable gas, and IF IT IS SAFE TO DO SO, close off the gas supply. If you are unable to do so, then do not try to fight the fire.
4. Grab an appropriate fire extinguisher (see Figure 12 to determine the right type).
5. Remove the pin. Note that if you are gripping the handle tightly, it will be difficult to remove the pin.
6. Test the fire extinguisher by giving a brief squirt of extinguishing agent off to the side BEFORE you approach the fire.
7. With your labmate watching from the exit door, and keeping yourself between the fire and the exit (and therefore with your back to the exit), approach the fire enough to be able to hit the fire with extinguishing agent.
8. When using an extinguisher, use the PASS system – Pull, Aim Squeeze, Sweep.
    a. Pull the pin on the extinguisher.
    b. Aim the extinguisher
    c. Squeeze the trigger or top handle
    d. Sweep the fire area with the extinguisher's spray from side to side, aim for the base of the fire, until the fire is completely out.
9. If the fire is still going when the extinguisher becomes empty, do NOT get another fire extinguisher. It is time to leave. Close doors behind you and pull the fire alarm on your way out.
10. As soon as possible, once you're in a safe location, contact Campus Security ext. **36111.** Describe the situation as a "fire out of control". It is likely that your call will be dispatched to the Kingston Fire and Rescue Department. Meet the fire fighters at the main entrance to Chernoff Hall

If the fire cannot safely be controlled with a fire extinguisher, then the following actions should be taken:

- alert all persons in the area of the fire emergency
- leave the area while closing doors and windows (where this can be done safely)
- activate the nearest fire alarm
- check to ensure that the area has been evacuated then leave the building to the nearest safe location
- phone the Emergency Report Centre (36111)

- be available to guide the Fire Department to the location of the fire

6.3 Chemical Spills


Contents of the spill kits

All spills should be cleaned up promptly, efficiently and properly. All individuals at risk due to the spill should be warned immediately.

Each lab in Chernoff Hall should have a spill kit. The kit contains absorbent pads, absorbent barriers (for preventing the spill from expanding), a disposal bag, gloves, and a suggestion sheet. It's better to use your own gloves because then you can check that the gloves will protect you from the liquid that has been spilled (see Section 5.3.4). Restock the kit if you use some of the materials. The barriers are available from Science Stores but the other components are special order.

If the spill involves **non-volatile, non-flammable and nontoxic material** then it should be cleaned up as directed by your supervisor. Most cleanups of liquid spills are facilitated by the use of an absorbent material that will neutralize the liquid where appropriate (spill kits are located in the safety locker found in each research lab). Cleanup can then be carried out using a dustpan, brush and appropriate protective equipment. The spill area should be washed following the cleanup.

If a hazardous chemical such as a **flammable, toxic or highly reactive substance** is spilled, immediately warn everyone in the area. Shut down all equipment and leave the area. Your supervisor should be notified immediately and will be responsible for the proper cleanup of the contaminated area. Any clothing that has been contaminated should be removed as quickly as possible and decontaminated where possible. Consult the appropriate SDS for spill cleanup procedures.

If in doubt as to whether a spill represents a danger, evacuate the room and then ask for advice from your supervisor or from security (36111 or the **RED** button).

Waste from chemical spills must be disposed of in an appropriate manner. Seek advice from EH&S.

6.4 Unplanned Ventilation Outage

6.4.1Outage in multiple labs

- Assess the extent of the ventilation failure in your area (is it just one fume hood, one lab, or the entire lab wing?)
- Shut down experiments that involves hazardous materials (make sure experiments are stable; shut off any gases, close chemical containers)
- Close fume hood sashes and lab doors
- Immediately report the ventilation issue to:
  - Your supervisor and surrounding labs
  - The Main Office (if during regular hours) ext. **32616** & press 0

- **If outside of regular work hours,** contact Campus Security ext. **36111**

➢ Exit the building and proceed to designated emergency assembly area (outside of Victoria Hall) and await further instruction from authorized personnel

6.4.2 Outage in a single lab or hood

- Confirm the failure is only affecting your fume hood
- Shut down experiments that involves hazardous materials (make sure experiments are stable; shut off any gases, close chemical containers, etc.)
- Close fume hood sash and post 'Out of Order' sign on fume hood
- Notify your supervisor about the fume hood failure
- Contact the Main Office (ext. **32616 & press 0** and/or recept@chem.queensu.ca) provide all details including your lab room #, fume hood # (e.g. fume hood # FH184XXX), etc.
- Do not continue any work in the fume hood until the fume hood has been repaired and ventilation restored

6.5 Elevator Failure

- Press the CALL button (it is behind a door flap in the South elevator). A call will be placed to campus security (36111). Please inform the responder of the situation. Be specific about the persons and goods that are in the elevator with you.
- Pressing the BELL button, will ring a local alarm that can only be heard in the vicinity of the elevator. It can be used to make passers-by aware of a stuck elevator but will not trigger an emergency response.

If you're walking by an elevator and hear the bell:

- Talk to person(s) trapped in the elevator and inform them about the CALL button. Also inform them that help will be called.
- Contact the General Office (ext. 32616 ext. 0 and/or recept@chem.queensu.ca) to report the elevator failure

6.6 Floods/Water Leaks

- If it is safe to do so, turn off the source of the water
- If the source of water is a cooling hose, and it is safe to do so, turn off any equipment that was supposed to be cooled by the water
- If water is coming into lab from emergency eye wash station or shower activation in the hallway, place a sorbent sock (from emergency spill kit) along the bottom of the lab entrance door to block water from entering lab.
- Stay out of the water to avoid slipping and to avoid electrocution
- Contact the Main Office (ext. **32616 & press 0** and/or recept@chem.queensu.ca) provide all details including your lab room #, location of the leak, etc.
- If water leak has been contained, and it is safe to do so, clean up excess water to avoid any damage. If after hours, contact Campus Security ext. **36111** and request that they dispatch custodial care to assist with cleaning up any excess water.

6.7 Reporting of Accidents

Minor accidents involving hazardous chemicals or the malfunction and/or breakdown of equipment must be reported to your supervisor. More serious accidents must be reported to the Head of the Department and/or the Department Safety Officer as well as to your supervisor. All accidents and incidents should be reported to the department using the **Incident/Injury Report Form** available on the departmental safety website. If the injured person is an employee (including grad students injured while they are TA'ing) then the **Workplace Safety & Insurance Board (WSIB) Form 7** is *also* required and should be submitted within 24 h to the department.

All accidents involving personal injury must be reported promptly to your supervisor who is responsible for ensuring that the procedures below are followed. If your supervisor is not immediately available, contact the Department Safety Officer or the Head of the Department.

- In the case of minor injuries that cannot be satisfactorily treated by first aid alone, or if there is any doubt, the injured person shall be sent or taken to the hospital emergency room, or doctor of his/her choice. Queen's employees should take along a completed copy of the relevant WSIB form(s) available from the departmental safety website or the Department Administrative Assistant. If this form(s) does not accompany the injured employee to the treatment centre then it must be filled out and sent to the treatment centre as soon as possible. Students, including grad students (as long as they weren't TA'ing at the time) are not employees and therefore don't have to do the WSIB form.
- In the case of injuries that are more severe, or there is doubt about the severity of the injury, and emergency assistance is required, call **36111** from an internal phone (or press the **RED** button). A SEVERELY INJURED PERSON MUST NOT BE MOVED without the advice of medical or ambulance personnel, unless an imminent danger is present.
- If it is necessary to call an ambulance, indicate the location of the injured person and the location of the nearest appropriate entrance to the building. If possible send someone to that entrance to lead the ambulance personnel to the injured person.

For all accidents involving critical injury or death:

- Immediately call 36111 for assistance
- As soon as possible, notify your supervisor, the Head of the Department (or Safety Officer), and the Department of Environmental Health and Safety. The latter will notify the appropriate government agencies.
- Do not touch anything associated with the accident, except for the purpose of saving life, relieving suffering or preventing unnecessary damage to equipment or property. The scene of an accident must be examined by the appropriate authorities

7. WASTE DISPOSAL

All chemical waste disposals are carried out by the Department of Environmental Health and Safety; sinks and garbage cans are not to be used for chemical waste disposal. Detailed instructions on chemical waste disposal can be found on the EH&S website: https://safety.queensu.ca/waste-disposal

The most common types of waste in a laboratory, other than normal garbage, are shown in Figure 13. More unusual kinds of waste, not shown, are biohazard waste, lecture bottles, radioactive waste, highly toxic waste (e.g. cyanides), and potentially explosive waste. Seek advice before getting rid of such types of waste. The instructions below assume that *none* of the wastes are contaminated with biohazard or radioactive materials.

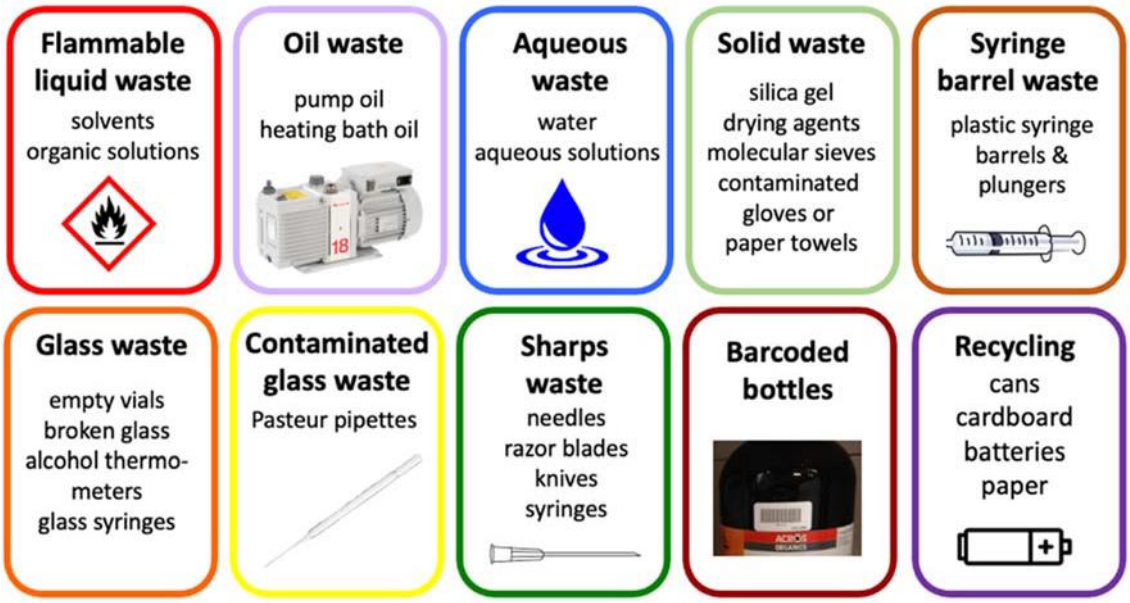


Figure 13. The most common types of waste in a laboratory, other than normal garbage.

7.1 Flammable liquids

Allowed: Organic solvents, organic liquids, organic reagents dissolved in organic solvents, halogenated solvents, combustible organics, and even

Forbidden: Don't dispose of aqueous waste here, but water already dissolved in organic solvents is acceptable.

Flame arrestor insert

Notes: It is acceptable to use a 1 L glass bottle in the fume hood as a collector of small amounts of organic waste, provided that the bottle is capped when not in use, and the bottle is labelled and dated. Once the bottle is full, either the bottle should be sent for disposal or the contents transferred to one of the large red flammable waste cans. **Do not fill the bottles to more than 90% of capacity**. Those cans must contain a flame arrester insert in the mouth of the container. See photo. Such inserts are available at Science Stores (ask for GE055).

Three mistakes shown here. The bottle is too big for temporary storage of flammable liquids. The cap should be on the bottle when it is not being used. The bottle is not clearly labelled as flammable liquid waste.

7.2 Aqueous waste

Allowed: aqueous solutions Forbidden: solids, flammables (beyond trace amounts).
Notes: List all known components. List the pH of the solution before disposal. If you regularly have a lot of aqueous waste, you can get a reusable can from EH&S. Collect aqueous acids separately from aqueous bases; otherwise an exothermic reaction might occur inside your waste bottle.

7.3 Solid waste

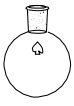
Allowed: silica gel, alumina, drying agents (e.g. molecular sieves, $MgSO_4$), contaminated gloves, paper towels
Forbidden: Liquids, reactive chemicals
Notes: A clean and empty wide mouth bottle, especially one of plastic, is best to collect such waste. Label the container and list all known components.

7.4 Mercury waste

Allowed: Mercury, mercury compounds, mercury thermometers
Notes: Use a container that will not release the mercury, even if dropped.

7.4 Oil waste

Allowed: Pump oil, bath oil, silicone oil
Forbidden: Solvents, water, solids
Notes: Use empty 4 L bottles (glass or plastic) to collect such waste.



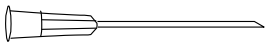
7.5 Glass waste

Allowed: Clean and non-contaminated glass items such as vials (empty), broken glass, glass syringe barrels & plungers, microscope slides, plate glass
Forbidden: Pasteur pipettes, mercury thermometers, needles, contaminated glass

*As of February 2021, all laboratory glass waste needs to be evacuated as 'contaminated glass waste' through EH&S. It is hoped that, in the future, it may be managed differently, but for now, it is treated as 'contaminated glass waste'

Contaminated glass waste 

Allowed: contaminated Pasteur pipettes, contaminated vials, contaminated broken glass
Forbidden: barcoded bottles, needles
Notes: Place such waste in a clean empty plastic bottle such as one that had previously held acetone. Label the bottle "contaminated glass waste." Send the bottle for disposal before it is over-full. Small vials and other glass can also be collected in 6 ml plastic bags and sent for hazardous waste disposal.



7.6 Sharps waste

Allowed: Needles (including contaminated needles), razor blades, knives, syringes

Forbidden: hazardous chemicals (beyond amounts that are normally contaminating the surface of used needles etc.)

Notes: A special sharps bin must be purchased. It is not re- usable. It will likely be labelled with biological hazard warnings. If the contents are not biological hazards, then deface the biological hazard warnings with black permanent marker. Label the bin either "Chemically-Contaminated Sharps" or "Biologically-contaminated Sharps". The bins are available in 1 gallon (GE080) and 10-gallon sizes (GE081) from Science Stores, and from EH&S. Don't try to re-cap or destroy syringe needles before discarding them.

7.7 Syringe barrel waste 

Allowed: Plastic syringe barrels & plungers Forbidden:
Needles, glass syringe barrels & plungers
Notes: This one is optional. You could put all this stuff in the sharps waste instead if you wish, but that might fill up the sharps waste quickly and force you to buy those sharps containers more often.

7.8 Barcoded Bottles 

Allowed: Empty and clean barcoded bottles.
Forbidden: Bottles containing chemicals; bottles that used to contain highly toxic or dangerously reactive chemicals (those should go into hazardous waste no matter how clean they are).
Notes: Do not rinse bottles into the drain. Use the "Empty Containers and Contaminated Debris" form at the EH&S website to request pick-up. You can bag several empty bottles together if they're small, but not if they contain barcodes. Don't remove or deface the label. If you wish, empty bottles can be re-used as containers for compatible waste, but in such a situation remove the bar code and return it to Science Stores. However, if a barcoded bottle is not empty, then use the "Chemical Waste Disposal" form to request pickup.

7.9 Recycling 

Put cans, including those that are used for secondary containment when chemical bottles are shipped, in the recycle bins outside the lab, but ONLY if the cans are free of contamination by anything hazardous.

Cardboard should be folded up and put in the big blue recycle bins.

There is a bin for recycling batteries on the 1st floor of Chernoff in the atrium. If the battery is leaking, seal it in a bag

7.10 Garbage

Allowed: Wood, paper, plastic, other non-hazardous materials

Forbidden: Chemicals, powders, sharps, glass, syringes, dirty chemical containers, clean chemical containers, food or drink containers, or anything contaminated with hazardous chemicals

Notes: Far too often a syringe needle is thrown into the regular garbage and a custodian receives a puncture injury. Please protect our custodians by sorting waste correctly!

7.11 Specialized hazardous waste

Seek advice before getting rid of biohazard waste, lecture bottles, radioactive waste, highly toxic waste (e.g. cyanides), and potentially explosive waste.

7.12 Old Equipment

Equipment that is sent out to be disposed of either by destruction or by recycling must be accompanied by a form certifying that the equipment has had all hazardous materials removed (e.g. mercury-filled thermometers, PCB-filled transformers, radioactive sources). These forms are available from the Department of Environmental Health and Safety, who will arrange for inspection of equipment prior to disposal.

Appendix I - OCCUPATIONAL HEALTH AND SAFETY ACT

The *Occupational Health and Safety Act* came into effect in Ontario in 1979. The purpose of this Act is to protect workers from health and safety hazards on the job. Both workers and supervisors have responsibilities under the terms of the Act.

SUPERVISORS AND THEIR DUTIES

Definition of a Supervisor
A "supervisor" is defined in the Act as a *person who has charge of a workplace or authority over a worker. A supervisor: is qualified because of knowledge, training, and experience to organize 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.*

A worker is an employee of the supervisor or their institution or firm. A professor who directs the research of a graduate student, postdoctoral fellow or other research associate is the direct supervisor of that individual if that individual is paid a salary for the research. A graduate student, postdoctoral fellow, or other research associate who does not receive a salary, being supported through other funds, is considered to be under the supervision of the professor who directs the individual's research.

Duties of a Supervisor

(1) A supervisor shall ensure that a worker,

- *(a) works in a manner and with the protective devices, measures and procedures required by this Act and the regulations; and*
- *(b) uses or wears the equipment, protective devices or clothing that their employer requires to be used or worn*

(2) Without limiting the duty imposed by subsection (1), a supervisor shall

- *(a) advise a worker of the existence of any potential or actual danger to the health or safety of the worker of which the supervisor is aware;*
- *(b) where so prescribed, provide a worker with written instructions as to the measures and procedures to be taken for protection of the worker; and*
- *(c) take every precaution reasonable in the circumstances for the protection of a worker.*

A supervisor also has special responsibilities in dealing with accidents involving personal injury or death; see REPORTING OF ACCIDENTS.

WORKERS AND THEIR DUTIES

Definition of a Worker

A "worker" means *a person who performs work or supplies services for monetary compensation*, which includes faculty, staff, teaching assistants, lab demonstrators, post-doctoral fellows, research associates, technicians, technologists, graduate students but NOT undergraduate students taking courses or visitors to the Department.

Duties of a Worker

The duties of a worker are:

(1) A worker shall,

- *(a) work in compliance with provisions of this Act and the regulations,*
- *(b) use or wear the equipment, protective devices or clothing that their employer requires to be used or worn;*
- *(c) report to their employer or supervisor the absence of or defect in any equipment or protective device of which they are aware and which may endanger themselves or another worker; and*
- *(d) report to their employer or supervisor any contravention of this Act or the regulations or the existence of any hazard of which they know.*

(2) No worker shall,

(a) remove or make ineffective any protective device required by the regulations or by their employer, without providing an adequate temporary protective device and when the need for removing or making ineffective the protective device has ceased, the protective device shall be replaced immediately;
(b) use or operate any equipment, machine, device or thing or work in a manner that may endanger himself/herself or any other worker; or
(c) engage in any prank, contest, feat of strength, unnecessary running or rough or boisterous conduct.

Students

Undergraduate students taking courses and unpaid graduate students are not employees (workers) under the Act. It is however the policy of the Department of Chemistry that the lab coordinators in undergraduate courses and research directors of graduate students shall act as the direct supervisors of these students, and shall assume the same responsibilities towards the students doing laboratory work under their direction as if the students where employees, AND the students shall act as workers and follow the duties of a worker.

Right to Refuse or to Stop Work Where Health or Safety are in Danger:

(1) A worker may refuse to work or do particular work where he or she has reason to believe that,
(a) any equipment, machine, device, or thing the worker is to use or operate is likely to endanger himself, herself or another worker;
(b) the physical condition of the workplace or the part thereof in which he or she works or is to work is likely to endanger himself, or herself; or
(c) any equipment, machine, device or thing he or she is to use or operate or the physical condition of the workplace or the part thereof in which he or she works or is to work is in contravention of this Act or the regulations and such contravention is likely to endanger himself, herself or another worker.
(2) Upon refusing to work or do particular work, the worker shall promptly report the circumstances of the refusal to the worker's employer or supervisor who shall forthwith investigate the report in the presence of the worker and, if there is such, in the presence of one of;
(a) a committee member who represents workers, if any;
(b) a health and safety representative, if any; or
(c) a worker who because of knowledge, experience and training is selected by a trade union that represents the worker, or if there is no trade union, is selected by the workers to represent them, who shall be made available and who shall attend without delay.

The *Occupational Health and Safety Act* can be found at the safety bulletin board in the 4th floor lounge of Chernoff Hall and at following Web address: http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90o01_e.htm

Appendix II - Classes of Incompatible Chemicals

Class of Chemicals	Incompatible with
Alkali and alkaline earth carbides, hydrides, hydroxides, metals, oxides and peroxides	Water, acids, halogenated organic compounds, halogenating agents, oxidizing agents
Azides, inorganic	Acids, heavy metals and their salts, oxidizing agents
Cyanides, inorganic	Acids, strong bases
Nitrates, inorganic	Acids, reducing agents
Nitrites, inorganic	Acids, oxidizing agents
Organic acyl halides, anhydrides	Bases, organic hydroxy and amino compounds
Organic halogen compounds	Group IA and IIA metals, aluminum
Organic nitro compounds	Strong bases
Oxidizing agents (chlorates, chromates, chromium trioxide, dichromates, halogens, halogenating agents, hydrogen peroxide, nitric acid, nitrates, perchlorates, peroxides, permanganates, persulfates)	Reducing agents, ammonia, carbon, metals, metal hydrides, nitrites, organic compounds, phosphorus, silicon, sulfur
Reducing agents	Oxidizing agents, arsenates, arsenites, phosphorus, selenites, selenates, tellurium salts and oxides
Sulfides, inorganic	Acids

Source: “Prudent Practices in the Laboratory: Handling and Disposal of Chemicals”, National Research Council, National Academy of Sciences, Washington, 1995.

Appendix III – Disposal Procedures, Hazardous Chemical

DISPOSAL PROCEDURES,
HAZARDOUS CHEMICALS

DEFACE - all containers that have hazardous material warnings **if** they no longer contain hazardous materials

SEGREGATE - incompatible materials (see back of pink form)

SEPARATE- unopened, unused chemicals from other material to be disposed

LABEL the **chemical name**, contaminants (including levels when known), concentration (molarity, dilution factor, etc.), must appear **on each individual bottle**, bag, box or container of chemicals or by-product. To comply with transport regulations, an **inventory** must be attached to **external** packaging (pink forms are provided for your convenience)

COMPLETE and ACCURATE IDENTIFICATION of all materials is the single most important factor in providing safe, environmentally sound and cost-effective hazardous waste management.

UNKNOWNS cannot be transported

Individual departments must bear all costs for analysis/identification when the identity of a material cannot be determined (with certainty) by the originating department.

PACKAGING

1. Solid Chemicals must be packed in cardboard boxes with an acceptable absorbent material such as vermiculite surrounding the individual containers (Styrofoam chips are not acceptable as they are reactive and non-absorbent).

2. Liquid Chemicals must be packaged as above, in their original shipping containers, or (if they are non-corrosive) in suitable non-breakable containers approved by E.H.& S.

3. Flammable Liquids must be placed in Solvent Disposal cans (the red ones with the wide mouth). Cans must be clean, with an intact flame arrestor and labelled according to point of pickup. Non-flammable, non-corrosive liquid material may be mixed with flammable material provided that the materials are compatible.