LAB & SHOP SAFETY PROGRAM

Acadia University
Lab & Shop Safety Program

This Lab & Shop Safety Program has been prepared to minimize the risk of injury and illness when working in Acadia's various laboratory and shop areas. Laboratories and science/engineering shops are potentially dangerous places, but the danger can be reduced to an acceptable level through the application of appropriate controls.

This Program deals primarily with chemical and biohazards, and does not deal in any depth with the other hazards such as:

- physical hazards (magnetic fields, lasers, and sources of infrared or ultraviolet radiation, noise and ultrasound), or
- radioisotopes

Guidance on safely managing these other hazards is found elsewhere on the **Lab & Shop Safety** page and the **Radiation Safety** page.

This Lab & Shop Safety Program provides valuable health and safety guidance, but by no means can it be all-inclusive. Laboratory and shop faculty, staff and students will need to consult material safety data sheets, manufacturers' recommendations and other documents to develop adequate safe work practices that are often unique to each situation.

Credit and thanks is given to Dalhousie University for much of this program's content, and for graciously allowing its use by Acadia.

Additional Reading:

1. Bretherick L., **Hazards in the Chemical Laboratory, 4th ed**. Royal Chemical Society, London, 1986.
2. **Prudent Practices in the Laboratory**, National Research Council, National Academy Press, Washington, DC, 1995.
WWW address: www.nap.edu/readingroom/books/prudent/
3. **Laboratory Safety Handbook**, Ordre des Chemistes du Quebec & Chemical Institute of Canada, Ottawa, ON, 1984.
4. **Safety in Academic Laboratories 6th ed.**, American Chemical Society, Washington, DC, 1995.
5. Furr A.K., **Handbook of Laboratory Safety,. 3rd ed** CRC Press, Cleveland OH, 1990.

1. THE LEGAL FRAMEWORK

As described in Acadia's **Statement of Commitment to Health & Safety…**

> ***Acadia University has established a healthy, safe campus community as one of its values in the University Strategic Plan. This value will be respected through the implementation of an effective Health & Safety Management System.***

This Lab & Shop Safety Program is a key component in Acadia's **OHS System**. That system has been developed to protect against injury and illness, and to meet the University's legal obligation to provide a safe and healthful environment. It is essential that all people who work and learn in our laboratories and shops be aware of the laws and regulations that place special responsibilities on those activities.

1.1 Occupational Health and Safety

The **Nova Scotia Occupational Health and Safety Act** sets out the general duties of employers and employees and describes how safety and health programs are to operate. Under the Act, the NS Government issues regulations that expand upon the Act's requirements. The **Workplace Hazardous Materials Information System (WHMIS) Regulation** is one such regulation which has particular application to Acadia's laboratories and shops. WHMIS requires that:

- chemicals be labeled or otherwise be properly marked,
- material safety data sheets be available to those who use chemicals, and that
- people who work with or around chemicals be fully trained.

1.2 Environmental Laws

Provincial environmental laws and regulations also affect laboratory operations by regulating the discharge of chemicals and by establishing allowable waste disposal practices. Sometimes, federal regulations also apply as is the case with PCBs, hazardous wastes, and ozone depleting or greenhouse gases.

1.3 Building and Fire Codes

Because they present unique hazards, special provisions of the National Building and National Fire Codes of Canada apply to the design and operation of laboratories and shops.

1.4 Transportation of Chemicals

Whenever dangerous goods are transported by road, rail, air or sea, the federal **Transportation of Dangerous Goods Act and Regulations** apply. Shippers must classify, label and package chemicals, and may need to place a dangerous goods placard on the vehicle that will transport them. Receivers of dangerous goods must maintain records of shipments received. The regulations specify that shippers and receivers of dangerous goods must receive training at least every three years.

For chemicals coming into Acadia laboratories and shops, the supplier and departmental storekeepers handle much of the work related to dangerous goods. But when a laboratory ships a chemical for analysis in preparation for a field program or as part of an inter-laboratory collaboration, the TDG Regulations still apply. In these cases, the laboratory assumes the responsibilities of the shipper. The laboratory supervisor must ensure that the shipment meets the requirements of the TDG Regulations.

1.5 Other Legislation

Other federal and provincial legislation affect some Acadia laboratories and shops. For example, the Nuclear Safety and Control Act establishes a system under which the University is granted a licence for laboratory use of radioisotopes. Other regulations apply to areas such as the use and storage of alcohol, drugs and infectious agents and the health and welfare of laboratory animals.

1.6 Responsibilities

Acadia University relies upon the people who work and learn in its laboratories and shops to help ensure a safe and healthful environment. People who are aware of their responsibilities and who discharge them carefully are critical to the success of our OHS System.

Directors, Chairs and Heads of Departments:

are responsible for ensuring that the appropriate departmental programs and procedures are in place so that there is compliance with University policy, as well as with health, safety and environmental legislation.

Laboratory and Shop Supervisors:

are responsible for ensuring that activities undertaken in their laboratories and shops are consistent with the Acadia University Statement of Commitment to provide a healthy, safe Campus Community. Supervisors shall ensure that:

- their laboratory or shop complies with University policies, programs and procedures, including those contained in our OHS System, and
- staff and students are properly instructed in and observe safe practices.

Faculty, Staff and Students:

are responsible for conducting themselves in a manner that does not endanger themselves or others, and that is in accord with both the University's policies, programs and procedures, and the supervisor's instructions.

1.7 Health & Safety Committees

As required by Nova Scotia's Occupational Health and Safety Act, Acadia has established a **University Joint Occupational Health and Safety Committee**. This steering-level committee meets regularly to discuss health and safety concerns and to develop recommendations for the University's administration. Several ad hoc **Health & Safety Subcommittees** report to the University JOHSC and provide wider participation and engagement.

2. RECOGNIZING THE HAZARDS

2.1 Health Hazards of Chemicals

2.1.1 Toxicity

We live in a chemical world. The food we eat, the clothes we wear, and even our bodies, consist of chemicals. To survive in this world, we have developed mechanisms that protect us from harm caused by chemicals. But, regardless of whether they are natural or synthetic, chemicals can overwhelm these defenses to cause harm.

2.1.2 Dose

> *"What is it that is not poison? All things are poison and nothing is without poison. It is the dose only that makes a thing not a poison"*
> - Paracelsus (1493 - 1541)

This concept of dose is fundamental to an understanding of the effects of chemicals on health. It is the dose which distinguishes an exposure which is harmful from one that is not. Dose involves the quantity of chemical and the exposure route and pattern. For many chemicals, we believe that there is a dose below which there is no harmful effect. As the dose increases above this threshold, the chemical begins to exert an effect. In some cases, the body is capable of repairing the damage that may have been done, and the exposure in this range is without adverse consequences. At still higher doses, however, the intense exposure overwhelms the defense mechanisms, causing irreversible damage. Finally, at even higher doses, the exposure can be fatal.

This dose-response relationship may not always apply. Some specialists believe that for some hazards, such as carcinogens, there is no threshold dose below which there is no risk. These people believe that any exposure carries some risk although it is well established that the magnitude of the risk increases with increasing dose.

2.1.3 Routes of Exposure

Chemical exposure generally occurs through ingestion, inhalation and direct contact with the skin or eyes. Accidental ingestion of chemicals in the laboratory occurs when food or drink become contaminated. It also occurs when people transfer chemicals from their hands to their mouths. Ingested chemicals may damage the digestive tract or they may be absorbed through the digestive tract and transported to organs where they can exert a toxic effect.

Inhalation exposure occurs when people inhale airborne gases, vapours, or particulates (dusts, fibers, mists and fumes). The term "aerosol" is used to describe tiny particulates that are suspended in air, and they can pose a significant inhalation hazard.

Inhaled chemicals can damage the nasal passages and the upper and lower regions of the respiratory tract. Chemicals that are inhaled may be absorbed through the lung and into the blood stream, where they can be transported to other parts of the body. Particulates, such as dusts and fibers, may be deposited in the lung where they can cause damage and disease.

Direct chemical contact can often cause skin damage. Skin damaging chemicals include oxidants, corrosive chemicals such as acids or bases and others (largely organic solvents) which can remove the skin's naturally occurring protective fats and oils. Other chemicals can be absorbed into the body through cuts or abrasions.

Some chemicals, such as methanol and dimethylsulfoxide (DMSO), can even pass through intact skin. Of even more concern is the fact that these chemicals, such as DMSO, can act as a vehicle to transport other dissolved chemicals across intact skin. Once such chemicals penetrate the skin, the blood stream can transport them to organs well removed from the site of absorption. This should always be considered when working with toxic or mutagenic chemicals dissolved in DMSO.

The eyes are made of very delicate tissue. Direct contact with many chemicals, particularly with corrosives, can quickly produce serious damage and even blindness.

2.1.4 Duration of Exposure

A chemical exposure can be of short duration, as might happen during a spill or other occurrence. Under such circumstances, the exposure might be reasonably intense. Such short, intense exposures are termed **acute**. As it is often easy to correlate adverse health effects with such acute exposures, we have a fairly clear understanding of the symptoms of an acute exposure, at least for the more common chemicals.

Chemical exposure can also be of longer duration and at levels below those which produce short term adverse health effects. Such exposures are termed **chronic**. Chronic exposures can also overwhelm the body's defenses and produce cumulative damage. Because of the prolonged exposure duration, it is often difficult to establish the impacts of chronic exposures, or to quantify the doses that are necessary to produce these effects.

Although we know a good deal about the impact of chronic exposure of many common industrial chemicals, we suspect that there is still much to be learned. Faced with such uncertainty, prudence suggests minimizing exposure to the extent possible. This principle is known as **ALARA – as low as reasonably achievable**.

Minimization of exposure is particularly important when the chemical is a suspected or confirmed carcinogen, since there may be no dose which is completely free of risk. Research laboratories often use some quite exotic chemicals, the toxicological properties of which are sometimes poorly known. Minimizing exposure is doubly important in such cases.

2.1.4 Chemical Elimination

Following chemical uptake by ingestion, inhalation or by absorption through the skin, the body responds in one of several ways. The body is, of course, able to use the wide variety of chemicals present in food. Some very simple chemicals are used directly. Other more complex chemicals are first broken down in a process called metabolism. The resulting simpler chemicals, called **metabolites**, are again used by the body.

The body also responds in a variety of ways to a laboratory chemical that gains entry into the body. Sophisticated systems exist to clear inhaled dusts from the lungs. Some chemicals are eliminated (or excreted) unchanged from the body in exhaled breath. Many others are excreted in urine. Just as many of the chemicals in food are too complex for the body to handle directly, the body must often first metabolize non-food chemicals. The metabolites may then be excreted from the body.

Unfortunately, the body is unable to effectively metabolize and/or excrete some chemicals. The body tends to store such chemicals and - given continued exposure - the chemical can reach levels that cause harm. For these chemicals, cumulative dose over time is clearly an important factor in determining the potential for harm.

2.1.5 Adverse Health Effects of Chemicals

Different chemicals have differing effects on the human body. Many of the toxic chemicals can damage different organs, depending on the severity, duration and type of exposure.

Corrosivity

Some chemicals, including most acids and bases, are highly corrosive to skin. Given sufficient exposure, some oxidizers can also corrode skin. When such chemicals come into direct contact with tissue, they cause serious and sometimes irreversible damage to skin, eyes and the mucous lining of the respiratory and digestive tracts. Corrosives are often encountered as solutions in water. Although corrosivity decreases as the concentration of the solution decreases, even reasonably dilute aqueous solutions of such corrosives as **hydrochloric, sulfuric**, and **nitric acid** and **sodium, potassium or ammonium hydroxide** can cause tissue damage on contact.

Irritation

Although they may not physically destroy tissues in the way that corrosives do, many other chemicals can irritate the skin, the eyes and the delicate tissue of the respiratory and digestive tracts. Most acidic or basic chemicals are irritants. So too are many organic liquids which can remove the oils and fats that naturally lubricate the skin. Irritated skin can appear red, dried, cracked or inflamed depending on the nature of the irritating action.

Some gases such as ammonia, chlorine, and the oxides of sulphur and nitrogen, are so strongly irritating to the lung that they cause a chemically induced pneumonia. Symptoms may not appear for some hours after severe exposure to these gases.

Allergies

Some chemicals provoke allergies - adverse reactions of the human immune system. Once a person is sensitized (has developed the allergy), very small exposures can sometimes trigger the allergic response. Chemicals such as nickel and its salts and formaldehyde can cause the reddening, swelling and itchiness at the site of contact that are typical of an allergic reaction of the skin. The allergic response may be immediate or it may be delayed for hours following the exposure. Such dermal allergies to chemicals, although not life-threatening, can be disabling. Chemically-induced skin allergies most often develop in people with a history of prolonged and repeated direct skin contact.

In addition to skin allergies, some chemicals cause respiratory system allergies with symptoms that resemble asthma. The response of a sensitized individual to an inhaled sensitizer can be life-threatening. Well recognized respiratory sensitizers include **diazomethane, formaldehyde, toluene diisocyanate** and many **related isocyanates**.

Effects on the Central Nervous System

Many chemicals, including most common solvents, act on the human central nervous system (CNS). Acute symptoms of exposure include headache, dizziness, drowsiness, loss of co-ordination and fatigue. Ethyl alcohol is just one of the many chemicals that produce such CNS effects. The symptoms of ethyl alcohol exposure are most often seen following ingestion, but inhalation over-exposure also produces CNS effects. Normal hexane, the straight-chain, six-carbon hydrocarbon, is particularly neurotoxic. It is much more dangerous than its homologous aliphatic hydrocarbons and even the other hexane isomers.

Effects on Other Parts of the Body

I. Lung

Many chemicals are harmful to the lung. Some solids such as asbestos and finely divided silica dust cause scarring of the very delicate air sacs of the lung. Prolonged exposure causes loss of tissue elasticity and thus interferes with respiration.

II. Liver

The liver is the body's chemical processing plant. The liver breaks down (metabolizes) into simpler molecules many chemicals that are taken into the body. As a result, long term exposure to many chemicals causes serious liver damage. Although normally a result of alcoholism rather than a work-related exposure, ethyl alcohol induced liver disease is a serious problem and is an example of the harm that long-term chemical exposure has done to the liver. Quite a few chemicals such as **phenol** and **pyridine** that damage the liver can also harm the kidneys.

III. Blood Forming Tissues

In addition to acting on the central nervous system, benzene can damage the bone marrow. As bone marrow is the site where the body manufactures red blood cells, high level benzene exposure can lead to anemia.

IV. Heart

A few chemicals, including many chlorofluorocarbons, can adversely effect the regulation of heart beat rate. Although these chemicals are generally quite mildly toxic, high doses can cause the heart to beat irregularly.

V. Blood

Carbon monoxide and cyanide anions have an especially strong affinity for hemoglobin - the oxygen carrying component of blood. Both bind to hemoglobin so strongly that they block the blood's ability to pick up oxygen in the lung. Fatal exposures, with asphyxiation as the cause of death, are not uncommon - especially from carbon monoxide. Engine exhaust or malfunctioning heating equipment are common sources when CO is implicated in a fatality.

Mutagenicity

Even using animal testing to demonstrate cancer risk is expensive and time consuming. As an alternative, researchers have turned to mutagenicity testing as a quick and inexpensive means to gauge cancer risks. Mutagenicity testing attempts to determine if a chemical can damage DNA. As cancer invariably involves altered genetic material, mutagenicity testing assumes that a chemical which can damage DNA in a mutagenicity test might also cause cancer. There are several different mutagenicity tests, but in general, they are carried out on cells rather that entire organisms. Many chemicals, including some quite common laboratory chemicals, are confirmed mutagens. Ethidium bromide, which is widely used in the life sciences, is a potent mutagen.

Cancer

Chemically induced cancer often does not appear for years or even decades following exposure. It is difficult to study cancer in exposed human populations because of this long latency period and the number of people needed to produce statistically reliable studies. Thus our knowledge of which chemicals cause human cancer is quite incomplete.

As a surrogate for human experience, researchers often test animals to identify chemicals that might cause cancer in people. Although there are uncertainties in extrapolating cancer data from animals to people, most authorities suggest treating animal carcinogens as if they are established human carcinogens.

Much of what we know about chemical carcinogens results from health studies carried out on people employed in heavy industry. Some of the better known industrial carcinogens include asbestos, benzene and vinyl chloride. Inhalation of asbestos fibres increases the risk of lung cancer, particularly among smokers. Asbestos exposure also causes mesothelioma, which is a cancer of the membrane which lines and separates the respiratory and abdominal cavities. Benzene exposure has been shown to cause leukemia in highly exposed workers. Workers who were highly exposed to vinyl chloride in the manufacture of polyvinyl chloride (PVC) have been shown to develop a rare liver cancer.

Laboratory chemicals believed to pose a cancer risk include **formaldehyde**, **acrylamide**, some compounds of **arsenic, beryllium, chromium VI** and **nickel, butadiene** and **hexachlorobutadiene**, some **chlorinated solvents** including **carbon tetrachloride**, **chloroform** and **methylene chloride**, **ethylene oxide** and a number of **aromatic amines** and **polynuclear aromatic compounds**.

As an arm of the World Health Organization, the International Agency for Research on Cancer (IARC) conducts literature reviews to assess the cancer causing potential of chemicals, chemical mixtures and manufacturing processes. IARC has reviewed the medical and scientific literature on hundreds of chemicals. Based upon the strength of the scientific evidence presented in these reports, IARC concludes its review by placing each studied chemical into one of several categories. The following table presents IARC evaluations for a selected number of chemicals. http://www.iarc.fr/ - select "Cancer Databases".

Some Selected Chemicals Evaluated by IARC

Group 1 Chemicals which are Carcinogenic to Humans:

4-Aminobiphenyl	Arsenic and some arsenic compounds
Benzene	Benzidene
Beryllium and some beryllium compounds	Bis(chloromethyl)ether
Chloromethyl methyl ether	Cadmium and some cadmium compounds
Chromium VI compounds	Ethylene oxide
2-Naphthylamine	Nickel compounds
Vinyl chloride	

Group 2a Chemicals which are Probably Carcinogenic to Humans:

Acrylamide	Acrylonitrile
Benzidine-based dyes	Benzo(alpha)pyrene
1,3-Butadiene	Diethyl sulfate
Dimethyl sulfate	Ethylene dibromide
Formaldehyde	Tetrachloroethylene
Trichloroethylene	

Group 2b Chemicals which are Possibly Carcinogenic to Humans:

Acetaldehyde	Acetamide
o-Anisidine	Antimony trioxide
beta-Butyrolactone	Carbon tetrachloride
Chloroform	Cobalt and some cobalt compounds
1,2-Dichloroethane	Dichlormethane
2,6-Dimethylaniline	1,1-Dimethylhydrazine
1,2-Dimethylhydrazine	2,4-Dinitrotolune
2,6-Dinitrotoluene	1,4-Dioxane
Ethyl acrylate	Furan
Hydrazine	Methyl methanesulfonate
Nickel	2-Nitroanisole
Nitrobenzene	Phenyl glycidyl ether
Potassium bromate	beta-Propiolactone
Propylene oxide	Styrene
Thiourea	Toluene diisocyanates
o-Toluidine	Vinyl acetate

Table 2.1

California also has an extensive electronic list of carcinogens and reproductive toxins available at the State's **environmental agency's web site (hyperlink to http://www.oehha.ca.gov/prop65/prop65_list/Newlist.html)**. The list - known as the Proposition 65 List - is used in connection with the Californian safe drinking water legislation.

Additional Reading:

1. Grant W. M., **Toxicology of the Eye, drugs, chemicals, plants and venoms**, 2nd ed., Charles C. Tomas, Springfield, 1974
2. International Agency for Research on Cancer. **Evaluations of Carcinogenicity to Humans,**. Web site http://www.iarc.fr/ - select "Databases".
3. State of California, Environmental Protection Agency, **Safe Drinking Water and Toxic Enforcement Act**, (Proposition 65 list); Web Site: http://www.calepa.ca.gov/publications/factsheets/1997/prop65fs.htm.
4. Sax N. I., **Dangerous Properties of Industrial Materials**, 8th ed., Van Nostrand Reinhold, Litton Publishing, New York, 1993.
5. Sittig M., **Handbook of Toxic and Hazardous Chemicals and Carcinogens, 2nd ed.**, Noyes Publications, New Jersey, 1985.

2.2 Flammability and Other Concerns

Many common laboratory and shop chemicals burn, so fire is a major hazard. Understanding the risks, taking the appropriate precautions and being prepared to react properly if a fire does occur, are key to preventing injuries and damage. Most of the information that follows focuses on the fire risk presented by organic liquids and gases. Although these liquids are serious fire hazards, laboratory and shop faculty, staff and students should not overlook the fact that ordinary combustibles, such a paper and wooden furniture, also burn. A fire in a laboratory or shop, whether it involves ordinary combustibles or organic liquids, represents a serious emergency.

2.2.1 The Fire Tetrahedron

The chemistry of fire is often described by the "fire tetrahedron", in which each edge represents one of the essential ingredients of a fire. Before there is a fire, there must clearly be a fuel. Air (or a source of oxygen) must also be present. In addition, a source of ignition is needed to start a fire. Heat produced by a flame, a heated surface or an electrical element are the usual sources of ignition. Even static electric sparks provide enough energy to start fires, in some situations. Finally, a free radical propagation mechanism, that sustains the fire, must operate. Removing any one of the fire tetrahedron edges prevents a fire or extinguishes one that is in progress.

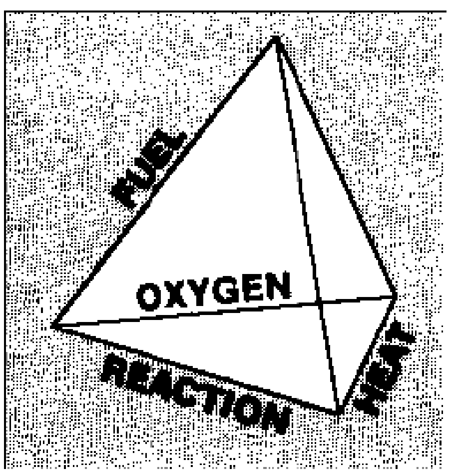

Figure 2.1 Fire Tetrahedron

2.2.2 The Flammable Limits

Although the principles are the same for both solids and liquids, laboratory and shop fires are more likely to involve liquids - particularly flammable solvents. When a flammable material burns, it is actually the vapour over the material which burns and not the liquid. But the mix of flammable vapour and air must be right to generate a flammable mixture. If insufficient flammable vapour is present, there can be no fire. Similarly, if there is insufficient oxygen present, there can be no fire.

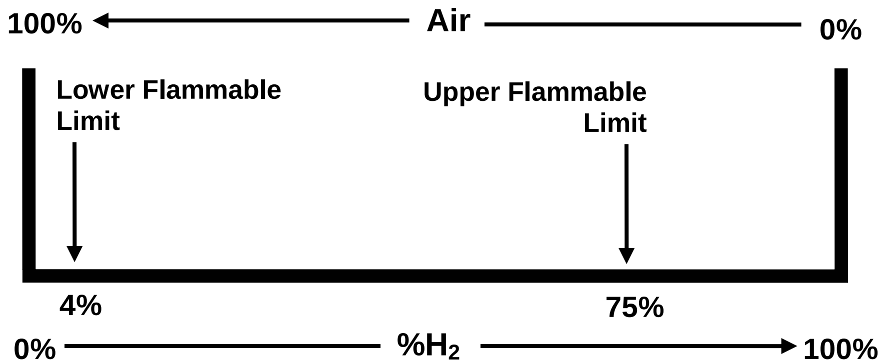

Figure 2.2

The diagram at Figure 2.2 represents the case for mixtures of hydrogen and air. At hydrogen concentrations less than 4%, there is not enough fuel present to support combustion. The mixture is said to be "too lean" to burn. At a concentration over 70%, there is too little oxygen present. The mixture is "too rich" to burn. Only at hydrogen concentrations between 4% and 70% is the hydrogen/air mixture correct such that a spark, flame or sufficient heat could start a fire. The minimum concentration, at which there is sufficient vapour present to form a flammable vapour/air mixture, is termed the lower flammable limit. The upper flammable limit is the highest concentration of flammable vapour which can still form an ignitable mixture with air. Some authorities use the terms upper and lower explosive limits.

Fire Properties of Some Common Laboratory Gases

	Boiling Point (C)	Flammable Limits lower	upper (%)	Autoignition Temp (C)
Acetylene	-83	2.5	100	305
Ammonia	-33	15.0	28.0	651
1,3-Butadiene	-4	2.0	12.0	420
Carbon Monoxide	-192	12.5	74.0	609
Dimethylamine	7	2.8	14.4	400
Ethane	-89	3.0	12.5	472
Ethylene	-104	2.5	36.0	450
Hydrogen	-252	4.0	75.0	500
Hydrogen Sulphide	-60	4.0	44.0	260
Methylamine	-6	4.9	20.7	430
Propane	-42	2.1	9.5	450

Table 2.2

2.2.3 Flash Point

With a flammable liquid, evaporation is necessary to form an ignitable vapour/air mixture. Evaporation, which produces the flammable vapour, is strongly dependent on temperature. For any organic liquid, there is a temperature – termed the flash point - at which evaporation produces just enough vapour to form an ignitable mixture. Clearly, those liquids (called flammable liquids) which have flash points at or below room temperature are especially serious fire hazards.

Many common solvents are flammable liquids. Technically the National Fire Code of Canada defines a flammable liquid as one with a flash point below 37.8° C and a vapour pressure (at 37.8° C) over 275.8 kPa. Liquids that must be heated to generate enough vapour to form an ignitable mixture present a much reduced fire risk. Liquids with flash points between 37.8° C and 93.3° C are termed combustible liquids. Although they still present a fire hazard, these combustible liquids are far safer than the flammables.

Fire Properties of Some Common Laboratory Liquids and Volatile Solids

	Boiling Point (C)	Flash Point (C)	Flammable Limits		Autoignition Temp (C)
			lower	upper	
Acetic Acid	118	39	4.0	19.9	463
Acetone	56	-20	2.5	12.8	465
Acetonitrile	82	6	3.0	16.0	524
Acrylonitrile	77	0	3.0	17.0	481
Benzene	80	-11	1.2	7.8	498
1-Butanol	117	37	1.4	11.2	343
tert-Butanol	83	11	2.4	8.0	478
Chlorobenzene	132	28	1.3	9.6	593
Cyclohexane	82	-20	1.3	8.0	245
Cyclohexene	83	-7	0.8	2.8	244
Dibutyl Ether	141	25	1.5	7.6	194
1,2-Dichloroethane	84	13	6.2	16.0	413
Diethyl Ether	35	-45	1.9	36	180
p-Dioxane	101	12	2.0	22.0	180
Ethanol	78	13	3.3	19.0	363
Ethylamine	17	-18	3.5	14.0	385
Ethyl Mercaptan	35	-18	2.8	18.0	300
Furfural	161	60	2.1	19.3	316
Gasoline	40-200	-43	1.4	7.6	280
Hexane	69	-22	1.1	7.6	225
Isoamyl Alcohol	132	43	1.2	9.0	350
Isopropyl Alcohol	83	12	2.0	12.7	399
Isopropyl Ether	69	-28	1.4	7.9	443
Methanol	64	11	6.0	36.0	464
Methylene Chloride	40	none	13.0	23.0	556
Methylethyl Ketone	80	-9	1.4	11.4	404
Nitromethane	101	35	7.3		418
Phenol	181	79	1.8	8.6	715
1-Propanol	97	23	2.2	13.7	412
Tetrahydrofuran	66	-14	2.0	11.8	321
Toluene	111	4	1.1	7.1	480
Trichloroethane	74	none	7.5	12.5	
p-Xylene	138	27	1.1	7.0	528

Table 2.3

2.2.4 Solvents

Solvents present serious fire and toxicity hazards. Although many factors influence the extent of the hazard, quantity is an important one.

Storage of flammable liquids at a reduced temperature, in itself, poses some special hazards. Ordinary, household refrigerators contain thermostats, lamps and other electric components which are potential sources of sparks. These electric connections are a serious hazard if flammable solvents are present - particularly in the event of a power failure. Cooling a flammable liquid in a refrigerator or freezer reduces the vapour pressure, sometimes to the point where the flash point is below the temperature in the unit. Under such conditions, a spark would not ignite the vapours. However, should the power fail, the temperature in the unit will rise. For many common flammable liquids, vapour concentrations in the fridge could climb, reaching the lower flammable limit. When the power is restored and the unit restarts, a spark could easily cause an explosion. Flammable chemicals may not be stored in a refrigerator or freezer unless the unit was manufactured for flammable chemical storage. Refrigerators and freezers that are used to store flammable liquids must carry a notice indicting that flammable liquids are present. Faculty, staff and students should understand that even water-based solutions of flammable liquids can still have flash points below room temperature. For example 24°C (75°F) is the flash point of a 50% solution of ethyl alcohol in water. Thus a 50% solution still meets the flammable liquid criteria and may only be stored in refrigerators or freezers designed for storing flammable liquids.

Additional Reading:

1. **Fire Protection Guide to Hazardous Materials, 10th ed.**, National Fire Protection Association, Quincy, MA, 1991
2. **Flammable and Combustible Liquid Code 30**, American National Standards Institute & National Fire Protection Association, Quincy, MA, 1993.

2.2.5 Reactive Chemical Hazards

Chemicals react with each other, sometimes with dangerous consequences. With over 10 million chemicals known, there are billions of possible chemical combinations. With this number of possible reactions and the number of reactions carried out, it is perhaps surprising that there are not more reactive chemical occurrences in university laboratories and shops. Because an unexpectedly dangerous reaction can have very serious results, faculty, staff and students need to understand the hazards. Even when the hazards are well known, occurrences are sometimes experienced. Most persons with even a basic understanding of chemistry are probably well aware that hydrogen and oxygen react explosively. Yet, in 1996, a hydrogen/oxygen explosion injured a researcher and did extensive damage at an Atlantic Canadian university.

2.2.6 Explosives

Some chemicals are unstable and can self-react - sometimes explosively. Others undergo rapid chemical change when subjected to heat (including the heat produced by friction) or impact. Some common heat or shock sensitive chemicals include:

- acetylides, azides (particularly metal acetylides and azides)
- nitrogen triiodide and other nitrogen halides
- organic nitrates
- many nitro and particularly poly nitro compounds (Picric acid is one such explosive with fairly wide laboratory use. Nitroglycerine and TNT - trinitrotoluene - are widely used commercial explosives.)
- perchlorate salts (particularly salts of heavy metals)
- many organic peroxides
- chemicals containing diazo (-N=N-) or the nitroso (C-N=O) functional groups

2.2.7 Organic Peroxides and Peroxide-Forming Chemicals

Organic peroxides are notoriously dangerous chemicals which can easily detonate. Although few laboratories use organic peroxides in appreciable quantities, many laboratories use chemicals which form peroxides by auto-oxidation reactions.

<u>Peroxide-Forming Chemicals</u>

Tetrahydrofuran and diethyl ether are two of a number of laboratory ethers that readily auto-oxidize, forming peroxides. The resulting peroxides are quite unstable and can be detonated by even a relatively minor shock. Chemical suppliers often stabilize the parent ethers with inhibitors which retard the formation of peroxides. But because the inhibitors interfere with some applications, many suppliers also sell peroxide-forming chemicals without the inhibitors. Some laboratories distil ethers to produce high purity solvents. These redistilled solvents also lack the inhibitor.

Exposing an uninhibited peroxide-former to air allows the peroxide to form. The rate of peroxide formation depends upon a number of factors, but with some ethers, dangerous amounts of peroxide can form within days. When the peroxide is insoluble in the parent ether, the risk of a shock-initiated explosion can be extreme. When the peroxide is more soluble in the parent ether, the explosion risk increases as the parent solvent evaporates. Again, the result can be a disastrous explosion. Within the past several years, a technician in an Atlantic Canada university laboratory suffered a serious injury when a small volume of uninhibited THF exploded. The inhibitor-free solvent had been exposed to air and the explosion was undoubtedly caused by the presence of peroxides.

Many common peroxide-forming materials are highly volatile. So, in addition to the peroxide problem, they often present a serious fire hazard.

Some Common Peroxide-Forming Chemicals	
acetal	**cyclohexene**
dibutyl ether	**diethyl ether**
1,4-dioxane	**ethylene glycol dimethyl ether**
isopropyl ether	**tetrahydrofuran**
Some Less Common Peroxide-Forming Chemicals:	
decahydronaphthalene	**diacetylene**
dicyclopentadiene	**divinyl acetylene**
methyl acetylene	**sodium amide**
tetrahydronaphthalene	**vinyl acetate**
vinyl ether	**vinylidene chloride**

Table 2.4

2.2.8 Exothermic Reactions

Some chemical reactions are strongly exothermic and the heat given off can produce a hazard. Although technically not a reaction, adding water to sulfuric acid is a well known exothermic "reaction". The heat produced when water is added to H_2SO_4 can cause splashing that can get the acid on skin or into the eyes.

2.2.9 Reactions Producing Gases

Chemical reactions that generate a gas can cause pressurization and explosions. In addition, if the gas is toxic, such as when acids react with cyanide salts to produce HCN, an inhalation exposure could be life-threatening.

Other reactions generate flammable gases. The reaction of alkali metals with protic solvents is perhaps the best known of this type of reaction. Even though most laboratory faculty, staff and students are well aware of the reaction and the flammable nature of the hydrogen it produces, this reaction is a fairly frequent cause of unwanted hazardous occurrences. Several years ago, an unintentional sodium/water reaction started a fire in a Canadian university research laboratory. The fire claimed one life, injured several other people and extensively damaged the laboratory.

2.2.10 Some Incompatible Chemical Combinations

See Table 2.5, below, for examples of incompatible chemical combinations. Uncontrolled reactions between chemicals listed on the left and chemicals or chemical families on the right can result in fires, explosions or in the release of otherwise dangerous substances. If you are unsure of the chemistry, refer to the MSDS and seek help from your supervisor. The carrying out of unauthorized chemical procedures is not permitted.

Incompatible Chemical Combinations

Acetic acid	- Strong oxidizing agents, strong bases
Acetic anhydride and acid halides	- Alcohols, amines, strong bases, strong oxidizing agents, water
Acetone	- Acids, bases, strong oxidizing agents
Alkali metals (Li, Na, K)	- Acids, alcohols, carbon dioxide, oxidizing agents, water
Alkali metal hydroxides	- Halogen and nitro-substituted organics, strong acids
Ammonia or ammonium hydroxide	- Acids, certain heavy metals such as silver and mercury, halogens, strong oxidizing agents
Ammonium nitrate	- Metal powders, strong reducing agents
Azide salts salts	- Acids, carbon disulfide, heavy metal
Charcoal (finely divided)	- Strong oxidizing agents
Chlorates	- Acids, reducing agents
Chromic acid (chromium trioxide, chromates and dichromates)	- Strong reducing agents
Hydrazine	- Strong oxidizing agents
Hydrogen peroxide	- Reducing agents
Metals (powdered) (in air, some are spontaneously combustible)	- Oxidizing agents
Nitric acid	- Chromic acid, strong bases, strong reducing agents
Oxalic acid	- Mercury and silver and their salts
Perchloric acid and perchlorate	- Certain heavy metal salts, reducing agents,
Perchlorate salts	- Strong acids salts and bases
Peroxides (some peroxides are shock sensitive)	- Reducing agents
Phosphorus pentoxide	- Alcohols, bases, water
Sulfuric acid	- Alcohols, bases, chlorates, perchlorates, permanganates, water

Note that there are many other hazardous chemical combinations!

Table 2.5

2.3 Hazards Related to Chemical Storage

Most laboratories store their chemicals in the containers they are supplied in. These containers are usually acceptable in Acadia's laboratories and shops. Because of their flammability and toxicity, however, storage restrictions are placed on solvents and other higher-risk chemicals.

Dozens of compressed gas cylinders are in use in laboratories across campus. Because they are so common, it is easy to forget that they pose a hazard. A full sized cylinder can be pressurized to 2,500 pounds per square inch. That is a lot of potential energy just waiting to be released. A broken valve on a fully charged cylinder can produce a rocket or shrapnel that can do a great deal of damage or claim a life. It is also easy to lose sight of the fact that there is a lot of gas in a cylinder. A leak in a small, poorly ventilated room or an elevator car can easily create an explosive or toxic atmosphere. Even if the cylinder contains non-toxic nitrogen or helium, a leak in a small room could reduce the oxygen levels to less than that required to support life. And, of course, compressed gases such as Fluorine, Hydrogen fluoride and Nickel tetracarbonyl are sufficiently toxic or reactive that they, along with similar gases, need to be used very carefully.

Many laboratories use plastic containers. When there are concerns about leaching contaminants from plastic containers, glass containers are probably a better choice. Although less popular today than in the past, some laboratories still use ground glass stoppered containers. However, some chemicals, such as concentrated sodium hydroxide, attack the glass and may "freeze" stoppers, particularly following prolonged storage. There are several instances in which ground glass stoppered containers are dangerous. Ground glass can catalyze the violent decomposition of some reactive chemicals. Other chemicals, such as some perchlorates, many peroxides and picric acid can be detonated by the friction of removing the stopper.

Although its use is declining, some laboratories use picric acid solutions. When picric acid is stored in glass stoppered bottles, a film of the solid yellow acid can be deposited around the stopper. Removing the ground glass stopper could detonate the acid and cause very serious injuries. Faculty, staff and students working with such dangerous chemicals should always check the material safety data sheet before beginning work.

2.4 Hazards Related to Waste Disposal

Inappropriate disposal of laboratory and shop chemicals along with regular trash, or by flushing them down a drain, could cause health, safety and environmental problems. Selecting an appropriate disposal technique requires knowledge of the physical, chemical and toxicological properties of the chemical. Although this topic is explored further in section 3, defining disposal options for the thousands of chemicals used in Acadia's laboratories and shops is beyond the scope of this program. Faculty, staff and students should discard waste and surplus chemicals only through the disposal programs that have been established in the various departments.

2.5 Biological Hazards

A biological hazard, or **biohazard**, is a biological substance that poses a threat to human health. This can include any organism and/or its toxin (a poison produced by a biological source) that can adversely impact humans. Biohazards can also include substances harmful to other animals.

Biohazards may include viruses, fungi, bacteria, prions (proteinaceous infectious particles) and parasites. Mammalian blood and body fluids, and certain types of nucleic acids such as DNA, should always be considered biohazards. The risk is magnified many times when working with human cell lines, blood, and other body fluids. Faculty, staff and students who are uncertain as to whether a material is biohazardous should always assume that it is, and take appropriate precautions.

As with most chemical substances, exposure to biohazards can occur through ingestion, inhalation, absorption and/or punctures. Faculty, staff and students should be especially aware that biohazards may be quite readily aerosolized during many routine lab procedures, especially those involving manipulation of liquids. Not all biohazards can infect by inhalation of aerosols, but for those that do, the risk of infection depends largely on the concentration and on the health status of the exposed individual.

2.6 Other Laboratory and Shop Hazards

2.6.1 Electrical Hazards

Laboratories and shops are full of complex equipment. If it is improperly maintained or worn out, this equipment can pose an electrical hazard. Although some hazards, such as frayed electrical wires and damaged plugs, are not unique to laboratories, they are serious. Typical lab and shop circuits carry 15 amp currents. Few people are aware that contact with as little as 0.1 amps can cause fatal electrocution. Therefore, even ordinary lab and shop electrical equipment carries enough current to severely injure or kill. Other equipment that uses higher voltage or current presents a particular hazard.

Most are aware that water and electricity don't mix. Of particular concern is a ground fault - a defect that allows electrical current to leak to an exposed conductive surface of a tool, device or appliance. Touching the conductive surface allows electricity to pass through a person on its way to ground, with serious and possibly fatal results. Ground faults are particularly dangerous if the person is in contact with a damp or wet surface, or plumbing which is very well-grounded.

If you have any concerns about the electrical safety of your laboratory or shop equipment, speak to your supervisor or departmental Safety Officer.

2.6.1 Mechanical Hazards

Many mechanical hazards are also present in laboratories and shops. Rotating equipment, in particular, can entangle clothing, hair or hands. An unguarded vacuum pump drive belt is an example of one such entanglement hazard. A centrifuge is another mechanical hazard. A high speed centrifuge stores enormous amounts of mechanical energy in the rapidly turning rotor. If high speed centrifuges are not properly cared for, the rotor can fracture and the fragments become lethal projectiles.

Faculty, staff and students sometimes work in wood, metal, glass blowing or electrical repair shops. Saws, routers, joiners, lathes, torches and similar equipment in these shops are frequent sources of injury, even in industrial operations where the employees have years of training and experience. No one may operate power equipment, torches or welding equipment in any Acadia shop unless trained and authorized to do so by the supervisor.

3.3 Extremes of Temperature

Many operations and many pieces of equipment found in laboratories and shops operate at a high temperature, presenting risk of burns and fire. Glass blowing, high temperature pyrolysis and plasma research are examples of these very high temperature activities. Laboratories and shops involved in very high temperature activities should carefully review their practices to ensure they do not place faculty, staff, and students at risk. Planning work in advance and attention to work in progress are normally sufficient to prevent occurrences. If there are questions, the advice of the supervisor and/or departmental Safety Officer should be sought.

Cryogenics is the study and use of materials at extremely low temperatures. The term "cryogenics," according to the National Institute of Standards and Technology (NIST), applies to all temperatures less than –150°C (–238°F).

Direct skin contact with a very cold surface, coolant, or cryogen can all do immediate damage to exposed skin on contact. The eyes are particularly susceptible – even small splashes of liquid nitrogen, or brief exposures to cold vapour or gas, may cause instant freezing of eye tissues and permanent damage.

The very cold cryogenic liquids (liquid nitrogen, liquid oxygen and liquid helium) boil at room temperatures. This boiling can cause eruptions and splashes, so tongs need to be used when placing and removing anything immersed in the liquid. Liquid nitrogen has a very low viscosity, which means that any spillage on clothing will penetrate much more readily than, say, water. Faculty, staff and students who work with these materials need to be continually aware of the potential for an injury.

They need to follow the proper procedures when dispensing these chemicals, particularly the liquids, and wear the appropriate protective equipment.

Cryogenic liquids and dry ice (solid CO_2) present several other hazards as well. Evaporation (or sublimation) releases very large volumes of gas. For example, as liquid nitrogen changes to gas at ambient temperature and pressure, the expansion ratio (the gas factor) is approximately 700. In closed containers, there is a potential for pressurization and, possibly, explosion. Each time a cryogen is used, the apparatus should be checked to make sure that dangerously high pressures will not develop. Those who use such cryogens also need to consider the volumes of gas produced. Although none of the gases are toxic, evaporation can change the atmospheric composition in a small space. "Inert" nitrogen, helium and carbon dioxide can all displace oxygen to produce an atmosphere in which the oxygen component is less than the 12% or so needed to support life. Someone inadvertently entering a small, unventilated room, where there has been a leak of only a few litres of one of these inert cryogenic gases, could lose consciousness almost immediately. Without immediate assistance, death is possible. Even more moderate oxygen deficiency can be very hazardous. One of the symptoms experienced when oxygen levels are reduced to 18-14% is faulty judgment. The resulting errors can easily cause injury.

Liquid oxygen presents a particular hazard. Evaporation enriches, rather than depletes the oxygen content of the air. Enriched oxygen atmospheres can create extreme fire hazards, especially in confined areas where flammables or combustibles exist. Liquid oxygen is, of course, a very powerful oxidizer. Contact between liquid oxygen and easily oxidizable materials can result in a violent explosion. Liquid oxygen is not widely used in Acadia's laboratories or shops. In view of the possibility of a very serious occurrence, supervisors planning to use liquid oxygen must review the project beforehand with the departmental Safety Officer.

3. PREVENTING HARM & OTHER LOSS

Preventing harm (i.e. injury and illness) to yourself and to others must be one of your primary considerations. It is at least as important as any other aspect of lab and shop work. The university's facilities and equipment must also be protected from occurrences, such as fire, that result in damage and other loss.

3.1 Controlling Hazard Exposure – The Hierarchy of Control

There must first be exposure to a hazard in order for it to cause harm. The Hierarchy of Control provides the universally-recognized approach to effectively prevent and control hazard exposure.

The Hierarchy of Control

1. **Elimination:** The task or process is redesigned to remove the hazard entirely. If hazard elimination is not successful or practical, the next most effective measure is:
2. **Substitution:** A hazardous material or process is replaced with a less hazardous one. For example, perhaps a pathogenic organism could be replaced by a non-pathogenic strain of that organism. Perhaps a particularly volatile solvent could be replaced with a less volatile one.

   If no suitable practical replacement is available, the next most effective control measure is:
3. **Engineering Controls:** The 3 primary engineering controls are **ventilation** (to evacuate or to dilute a hazard), **enclosure** and **isolation**. A guard covering a vacuum pump's drive belt is one example of enclosing a hazard. A closed reaction process is another. A lab fume hood is a combination of ventilation and enclosure.

   The next most effective control measure is:
4. **Administrative Controls:** Administrative controls include procedures, training, scheduling, signs, etc. For example, limiting a person's duration of exposure to a particular chemical is one example of administrative control. Another example is implementing a procedure that prohibits eating and drinking in laboratories.

   The effectiveness of administrative controls depends largely on human behaviour. Compliance with these controls is necessary in order to prevent harm.

   The last, and often the least effective control measure to be considered should be Personal Protective Equipment (PPE):
5. **Personal Protective Equipment (PPE):** To be effective, PPE must be properly selected and often must be fitted to the person who uses it. Users must be trained in the function and limitation of each item of PPE.

   PPE is often considered inferior to higher-level controls because:
   - it protects only the person wearing or using it. Ventilation, for example, is a superior control since it generally protects everyone in the area.
   - it is located immediately at a person's body; failure of PPE could result in direct exposure to the hazard.
   - as with Administrative Controls, the effectiveness of PPE depends largely on human behavior.

In most cases, a combination of controls is chosen to provide primary, secondary, and subsequent levels of protection. As a general rule, the degree of control should be proportional to the risk (likelihood of exposure x consequence).

3.2 Recognizing Elevated Susceptibility to Harm

Working in some laboratories and shops may pose special risks for persons with certain medical conditions. It is essential that those persons recognize the risks and discuss appropriate options with their lab or shop supervisor(s). Conditions that may require special measures include:

- pregnancy or nursing of a child,
- compromised immune system,
- epilepsy and similar conditions, and
- Certain chemical sensitivities.

Supervisors are reminded that they must hold personal information in strict confidence.

3.3 General Lab and Shop Safety Practices

There are a number of safe practices that apply to all lab and shop activities:

- Always wear eye protection, lab coats and closed-toed shoes when working in laboratories and shops.
- Do not store food or beverages, or consume food or beverages in laboratories or shops.
- Pipetting by mouth is strictly prohibited.
- Behave responsibly. Laboratories and shops are high-risk areas, and inappropriate behaviour can needlessly put people at risk.
- Only use lab and shop equipment that you have been trained to operate.
- Ensure that all guards and safety devices are in place before operating equipment.
- Tie back or otherwise secure long hair or loose clothing when working around mechanical equipment.
- Warn co-workers about any unusual dangers associated with work you are doing.
- Follow the supervisor's instructions. Do not carry out unauthorized experiments.
- Wash your hands <u>thoroughly</u> before leaving the laboratory or shop. This is a surprisingly effective way of protecting your own health, and the health of others.
- Keep work spaces organized and clean, and promptly clean up spills.

3.4 Working Alone

Some laboratory and shop procedures require long hours and it is often not possible to work a "9 to 5" schedule. Working alone, however, can be dangerous. Without someone around and able to help, an occurrence that would ordinarily be fairly minor could be very serious. If you must work alone:

- Do so only with your supervisor's permission.
- Assess the hazards. Only work alone if the nature of that work makes an operation relatively safe (e.g. recording data, operating an instrument, counting plates). Such tasks typically involve routine procedures that experience has shown to be of low risk. Even with lower-risk tasks, ensure that your presence in the laboratory or shop, and your expected time of work completion, is known by at least one other person who will check on you. Acadia Safety & Security can assist.
- Work of a clearly hazardous nature (e.g., tasks involving high energy, acute toxics (e.g. cyanogen bromide, hydrogen sulfide, carbon monoxide, explosives, volumes of cryogenic liquids, or high pressure situations) must not be conducted alone. Such activities must be scheduled during normal working hours and performed when another person is present. That second person must be capable of helping, if an emergency should arise.

3.5 Ensuring Safe Unattended Operations

Some lab procedures must run for extended periods, and people may not always be present. Most unattended procedures do not pose significant health or safety risks. However, in some cases, the failure of a control, the interruption of utilities or a mechanical failure could cause serious harm or damage. Such failures include:

- loss of cooling capacity resulting from interruption in supply of coolant or leakage in coolant lines,
- interruption in supply of water, propane, electricity, compressed air or other gas,
- failure of a stirrer, thermostat, level indicator, pump, motor, fume hood or other mechanical device, or
- failure of a flow regulator or temperature controller.

When a heater is used in an unattended experiment, a variac (variable transformer) can sometimes be a safer means of controlling the heater than a thermostat.

When planning an unattended operation, faculty, staff and students must perform a risk assessment that carefully considers the possible implications of such failures. A protocol must then be developed that minimizes the likelihood and the consequences of a failure. Part of the protocol should be the posting of a notice, outside the laboratory or shop, identifying that an unattended operation is in progress and any appropriate precautions that should be taken.

If higher-risk unattended procedures must be undertaken, redundant fail safe controls or interlocks are required.

3.6 Safe Storage and Handling of Chemicals

The way in which chemicals are stored and handled has a direct impact on laboratory and shop safety.

3.6.1 General Safe Storage and Handling Requirements

Store Chemicals

- in minimum practical quantities, away from entrances.
- protected from exposure to excessive heat or direct sunlight.
- above floor level, on shelves not higher than shoulder height.
- on shelves with a back which prevents chemicals from falling off the rear of the shelf.
- separately from other incompatible chemicals .
- in the supplier's original container, or in a compatible container that provides adequate protection for the contents and is properly labeled.
- with containers tightly capped or covered, and oriented so that labels can be easily seen.

When Handling Chemicals

- where risk of exposure exists, use flammable and toxic chemicals only in fume hoods.
- avoid using solvents and other flammables around sources of ignition.
- be aware of and observe incompatibility concerns. Never mix incompatible chemicals without taking precautions to protect yourself and others in the laboratory.

3.6.2 Safe Storage of Solvents and other Flammables

Safe solvent storage is intended, in large part, to reduce the fire hazard by limiting the quantities of solvents in laboratories. In recognition of the risk that solvents present, Acadia limits solvent container sizes and volumes of solvents kept in labs and shops. Container sizes or volumes in excess of these limits must be stored in approved solvent storage rooms that are properly ventilated and have fire/explosion protection and secondary spill containment. Ground and bond to prevent accumulation of static electricity when dispensing solvents and other flammable liquids from bulk containers.

In labs and shops, store solvents:

- in glass containers holding no more than 5 L. or in safety cans holding no more than 25 L (diethyl ether may only be stored in containers holding 1 L or less).
- in flammable storage cabinets, or in refrigerators or freezers designed for storage of flammable liquids.

Store acetic acid as a flammable liquid rather than an acid.

3.6.3 Separation of Incompatible Chemicals

Storing incompatible chemicals separately is an important means of avoiding inadvertent contact between them. Generally, chemicals are grouped into the following incompatibility classes.

- Acids and bases
- Solvents
- Dangerously reactive chemicals
- Oxidizers
- Other reagents

Chemicals in each of these incompatible classes must be stored separately. Professional judgment must be exercised in devising a storage system which properly separates incompatible chemicals in any particular laboratory or shop. **Always refer to MSDSs for guidance**, and observe the following general guidelines:

- Store acids and bases separately from other chemicals.
- Provide a secondary means to contain a liquid spill.
- Exercise care when removing acids or bases or returning them to storage as mixing of acids and bases can generate a good deal of heat.
- Store reactive chemicals with regard for their reactive properties well separated from incompatible chemicals.
- Store oxidizers separately from combustible materials and particularly from reducing agents.
- Store perchloric acid as an oxidizer rather than as an acid.

3.6.4 Reducing the Risk of Unwanted Peroxide Occurrences

- Avoid using peroxide-forming chemicals, when possible.
- Buy only inhibited ethers, when possible.
- Buy peroxide-forming chemicals in the smallest quantities possible to limit the volumes exposed to air.
- Store in a cool location and protect from exposure to light or air.

- Record the date that containers are opened.
- Use peroxide-forming chemicals with regard for their reactivity, toxicity and flammability.
- Work in a fume hood with the sash lowered as far as is practical.
- Use laboratory techniques that prevent exposing inhibitor free peroxide-formers to air.
- Consider using an explosion shield.
- Wear eye protection at all times while in the laboratory.
- Test containers for peroxides at least monthly. Use commercial peroxide test strips, or add 9 ml. of ether to 1 ml. of a saturated solution of KI. Mix carefully. A yellow colour indicates the presence of peroxides. Record date and result of test. If test shows the presence of significant amounts of peroxide, remove the peroxide or contact the departmental Safety Officer for advice.
- Treat any peroxide-forming chemical as an extreme shock sensitive explosion hazard unless you are sure it is free of peroxides.
- Do not move the container if crystalline deposits or viscous liquids form in peroxide-forming chemicals. Call the departmental Safety Officer for help.

3.6.5 Avoiding Unexpected Reaction Hazards

- Seek help or advice from your supervisor if you are not familiar with the reaction you are planning or the reactants that you will use.
- Always observe precautions outlined on the MSDS when working with an explosive or dangerously reactive compound.
- Work in a fume hood with the sash lowered as far as possible when working with dangerously reactive chemicals. Post information on the nature of the hazard to alert others to the danger.
- Consider using an explosion shield, a face shield or safety goggles in addition to usual protective equipment and clothing.

3.6.6 Compressed Gas Safety

- Minimize the amount of compressed gas that is stored in labs.
- Never allow a cylinder to fall or bang against another cylinder.
- Always store cylinders in the upright position, in a well-ventilated area.
- Ensure that valves are tightly closed when cylinders are not in use.
- Place valve protection caps on compressed gas cylinders that are in storage or are not being used.

- Cylinders must be secured to prevent them from falling, and must be protected from having objects fall on them.
- Stored cylinders must be grouped by type of gas.
- Store full and empty cylinders separately, such that they cannot be confused.
- Flammable gas and oxygen cylinders must be kept at least 20 feet from flammable liquids and highly combustible materials.
- Store cylinders a safe distance (at least 20 feet) from all operations that produce flames, sparks, or result in excessive heat.
- Oxygen cylinders must be separated from flammable gas cylinders by at least 20 feet, or by a non-combustible barrier at least 5 feet high having a fire resistance rating of at least 0.5 hours.
- Check Material Safety Data Sheets to ensure that incompatible compressed gases are not being stored together.
- Do not store compressed gas cylinders in areas where they can come in contact with corrosive chemicals.
- Do not place compressed gas cylinders against electrical panels or live electrical cords where the cylinder can become part of the circuit.
- Do not lift compressed gas cylinders by the valve or the protective cap.
- Use safe lifting techniques when handling cylinders. When using a dolly, secure the cylinder to prevent it from falling.
- Signs must be used to identify the gases stored in an area.
- Use only the regulator designed for use with the particular gas. If you have any doubts, contact the supplier.
- It might be prudent to use flow limiting valves (with some very toxic gases) and antiflash back devices (with flammable gases). More information on these devices is available from the supplier of compressed gases.
- Never transfer gases between cylinders.

3.6.7 Safe Storage & Handling of Liquid Nitrogen (these precautions generally apply to other cryogens)

- In order to control the risk of asphyxiation, areas where liquid nitrogen is stored and handled must be sufficiently well ventilated, or sufficiently large, to ensure that the oxygen concentration does not fall below 19.5 %.
- Only those who have been suitably trained may fill dewars. This is a potentially dangerous operation.
- Warm dewars should be filled slowly to reduce temperature shock effects and to minimize splashing.

- Care must be taken to avoid the formation of liquid oxygen in cold-traps that are open to air or the increase of liquid oxygen content in a flask of liquid nitrogen that has been cold for a long period (liquid oxygen has a blue water-like appearance). Most liquid nitrogen containers are closed except for a small neck area and the nitrogen vapour issuing from the surface forms a barrier which keeps air away from the liquid, thus preventing formation of liquid oxygen.
- Safety glasses, lab coats and closed toed shoes are required for all lab and shop operations. Additional protective equipment and clothing is necessary when handling liquid nitrogen. This includes faces shields and loose-fitting, non-absorbent insulated gloves. Lab coat cuffs should cover the ends of the gloves to prevent a splash from entering the glove. A splash resistant apron will give added protection where dewars are being lifted or carried, or wherever there is a high risk of splashing (e.g. during filling operations).
- Gloves are intended only to protect the hands against contact with cold surfaces or splash, not against immersion in liquid nitrogen. Ensure that tongs or other appropriate tools are used for handling objects.

3.6.8 Working Safely with Pressurized Apparatus:

- Guard all laboratory equipment that operates at reduced or elevated pressure. In the event of a rupture, the guard will protect laboratory staff from flying debris.
- Post notices to warn others of the danger of pressurized equipment.
- When setting up distillation or similar apparatus, double check to ensure that you are not inadvertently about to heat a closed system.

3.6.9 Moving Chemicals

Faculty, staff or students should not move chemicals between Acadia buildings without authorization of the departmental Safety Officer.

Care is needed to prevent occurrences while moving chemicals between and within buildings. This is especially critical when chemicals are being moved through public areas. Follow these guidelines:

- Moving chemicals as received in the supplier's original shipping package is generally the safest approach.
- Use a cart to move chemicals in containers larger than can be easily carried in one hand. Secure containers to prevent spills.
- Move critical liquids in a leak proof secondary container. For example, move inorganic acids and other corrosive liquids in rubber buckets.

- Be particularly cautious when using elevators or stairs to move chemicals. If possible, elevators should be avoided. Because elevator cars as so confined, a spill or leak of a chemical could quickly result in an overexposure or a fire.

3.7 Biosafety – The Control of Biohazards

In recent years, there has been considerable development in biosafety principles and practices. Several excellent biosafety documents have been produced by highly-credible sources. Acadia has identified three such documents for use by faculty, staff and students in our programs:

- Laboratory Biosafety Manual, 3rd edition. World Health Organization. Geneva, 2004

http://www.who.int/csr/delibepidemics/WHO_CDS_CSR_LYO_2004_11/en/print.html

- Biosafety in Microbiological and Biomedical Laboratories (BMBL), 4th Edition. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, and National Institutes of Health.

http://www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm

- Lab Bio-safety Guidelines, 3rd Edition 2004. Public Health Agency of Canada.

http://www.phac-aspc.gc.ca/publicat/lbg-ldmbl-04/index.html

3.8 Fume Hoods

3.8.1 Fume Hood Principles

In many laboratories, the fume hood is the single most important safety feature. In essence, a fume hood is a ventilated box with a movable transparent window through which one can see what is happening in the hood. In most cases, you access the hood interior by raising the front window. In others, a transparent pane is slid to one side. As fires and explosions can happen in fume hoods, the window is made to withstand most fume hood occurrences.

Fume hoods are vented to the outside, where dilution reduces exhausted contaminant concentrations to acceptable levels. To pull air through the fume hood and force it out of the building, a fan is be mounted in the exhaust duct.

In order to protect against exposure to chemicals, a fume hood must efficiently trap contaminants that are released in the hood. To do that properly, fume hoods must channel the air into the hood with a minimum of turbulence. Fume hoods achieve this smooth, turbulence-free flow by incorporating a contoured face on the side walls and a lower front edge that is shaped like an air foil. In a properly designed unit, air sweeps into the hood and across the working surface. Some of the air is expunged through openings in the rear baffle near the fume hood floor. The remaining air rises along the back wall to exhaust through baffle openings in the upper part of the hood. If there is an imbalance between the air flow through the lower and upper baffle openings, a vortex develops in the upper part of a hood. A vortex actually moves contaminated air toward the face of the hood. In the worst case, the vortex will propel contaminated air back into the lab.

The rate at which air flows into the fume hood is an important factor in determining the unit's effectiveness. As with many things, more is not necessarily better. When the window is fully open, air should flow into the fume hood at speeds of between 80 and 120 ft/minute. Higher air speeds create turbulent air flow that can cause contaminated air to spill out of the hood. As the window is closed, the fume hood face opening decreases. Since most of Acadia's fume hood fans operate at constant volume, the velocity of the air flowing into the hood would increase when the window, or "sash", is lowered. To prevent the air velocity from increasing to the point where turbulence develops, some hoods have a compensating baffle over the window that keeps the face area somewhat constant.

Persons walking in front of a hood, the opening of laboratory doors, use of portable fans, and even the position and design of the diffuser that supplies fresh air to the laboratory, can all cause air currents at the fume hood face. These currents can impair fume hood performance and expose persons to contaminants.

Work practices can also dramatically affect hood performance. Fume hoods most effectively capture vapours created at least 15 cm into the fume hood. Placing sources of contaminants closer to the face of the hood can allow toxic materials to escape into the lab. Obstructions within the hood also influence air flow patterns and can impair performance. Placing bulky pieces of equipment or allowing excessive accumulation of storage in the hood can disrupt design airflow patterns. Shelves along the walls also interfere with air flow and contribute to an escape of contaminants into the lab. When you need to put a bulky piece of equipment in a fume hood, you should raise it about 2 – 4 cm, in a secure way, using rubber stoppers or similar spacers. Raising the equipment allows air to sweep the floor of the hood and minimizes the disruption in air flow.

3.8.2 Ensuring that Fume Hoods are Appropriate for High-risk Work

Care must always be taken with all "general chemistry" work that is conducted in fume hoods. Some work, however, poses elevated risks that require additional precautions. Two examples are:

- Use of perchloric acid, especially if heated above ambient temperature, and
- Use of volatile radioisotopes.

Higher-risk work often requires specially designed and equipped fume hoods. For example, when perchloric acid is heated above ambient temperature, it will vaporize and may condense on hood, duct and fan components. As a result, explosive perchloric salts and esters may form and accumulate. A proper perchloric acid hood is built with welded stainless steel hood surfaces, ductwork, and fan to minimize the corrosive and reactive effects. More importantly, perchloric acid hoods have a wash-down system of water fog nozzles dispersed throughout the hood and exhaust system. By washing down the hood following each use of heated perchloric acid, any materials deposited within the system are removed, preventing the buildup of hazardous perchlorates.

When performing higher-risk lab work, always ensure that the fume hood is suitable for that purpose and that it is working properly. Discuss any concerns or questions with your lab supervisor. Acadia's **Radiation Safety Officer** should be consulted when questions arise regarding the use of radioisotopes in fume hoods.

3.8.3 General Points for Safe Fume Hood Use:

- Verify that the fume hood is drawing air by checking the fume hood monitor, if there is one, or by taping a tissue or ribbon to the sash and checking its position. If the draw does not seem sufficient, report that condition to the Laboratory Supervisor, to be called in to Physical Plant Services.
- Utilize the hood with the sash positioned at the arrow on the fume hood inspection sticker (usually this is between 25 and 45 cm in height). This will ensure adequate capture efficiency and allow the sash to act as a protective shield.
- Do not put your head in the hood when contaminants are being generated (this sounds incredibly basic, but is a common occurrence).
- Perform all work and keep all apparatus at least 15 cm into the hood.
- Always wear appropriate eye protection and a lab coat when working around a fume hood.
- The fume hood is NOT a storage cabinet! DO NOT store chemicals or apparatus in the hood. These stored materials can obstruct the air flow or exacerbate an unwanted occurrence in the hood.
- Hoods should generally not be used to dispose of toxic or flammable chemicals (through evaporation).
- Do not block the slots in the hood baffle with containers or apparatus.
- Electrical receptacles (including power strips) must be located outside of the fume hood. Ensure that there are no sources of ignition or spark, including variable transformers (Variacs), when flammable liquids or gases are present.
- If the hood is used for semi-permanent experiments, post the name of the person in charge, experiment title, and appropriate precautions.
- Keep fume hood sashes closed down when the hood is not in use. This will act as an effective shield in the event of an unexpected release or fire.

3.8.4 Ensuring Proper Function of Fume Hoods and Reporting Problems

The proper function of fume hoods is critical to maintaining a healthy and safe laboratory environment.

Users must help ensure proper operation of hoods by routinely performing these simple maintenance checks:

- Inspect the physical condition of the hood interior, sash and visible vents.
- Check sash for ease of operation.
- If a local switch is available, confirm that the fume hood is turned on.
- Check for adequate airflow/capture velocity at the face of the hood (observe the ribbon or other indicator).
- Check the condition of any utility services inside the hood (compressed air, gas, vacuum, etc.).

If you believe that a fume hood is not functioning properly, do the following:

- Immediately discontinue use of the fume hood and inform your lab supervisor.
- If it is confirmed that the fume hood is not functioning properly, remove and relocate apparatus and chemicals. Ensure that no other lab equipment is vented into the hood.
- Close the sash to prevent the possible back-drafting of contaminants.
- Tape a **Fume Hood Out of Order** sign on the pane (click on the hyperlink to access and print a copy of the sign).
- Request that a repair order be submitted to Physical Plant Services. This is normally coordinated through the Building Manager or his/her designate.

3.9 Other Lab and Shop Equipment

Although a summary of basic health and safety considerations for select equipment appears below, Acadia's laboratories and shops contain a vast assortment of machines, equipment and devices that is far too extensive to properly address in a Lab & Shop Safety Program. Always refer to and follow the manufacturers' recommendations for safe operation and proper routine maintenance.

3.9.1 Biological Safety Cabinets

Biological Safety Cabinets (BSCs) are sometimes called laminar flow cabinets or biohazard cabinets. BSCs are among the most effective and the most commonly used primary containment devices in laboratories working with biological hazards. Many of the safety principles that apply to fume hoods also apply to BSCs.

Refer to the **Public Health Agency of Canada's Laboratory Safety Guidelines**, **Chapter 9**, for a description of BSCs and safe practices.

3.9.2 Autoclaves

Autoclaves use steam for decontaminating biohazardous waste and for sterilizing glassware and microbiological media and liquids. Autoclaves are potentially very dangerous devices, and should only be used by persons who have been trained in their proper operation.

Guidelines for Safe Autoclave Use:

- Do not overload the chamber. Autoclaves must be loaded carefully to allow for steam penetration, since steam must contact pathogens in order to destroy them.
- Wrap packages to allow for steam penetration; aluminum foil does not allow effective penetration, and should not be used for wrapping.
- Avoid overpacking of autoclave bags, and do not stack containers.
- Do not seal bags or tightly close bottles and other containers.
- Longer times are needed for larger loads, large volumes of liquid and denser materials.
- Autoclaving can drive volatile chemicals from waste and expose building occupants to toxic chemicals. Do not autoclave such waste unless there is provision for capturing and venting hazardous vapours.
- Stand back when opening the autoclave door to avoid being scalded by escaping stream.
- Because of pressure build-up, superheated liquids can 'bump" when they are removed from the autoclave. Unless proper containers are used, this can cause a spray of boiling liquid. Lids must let air flow back into a solution as it cools, otherwise there is an implosion risk as the solution cools.
- At least monthly, a heat-resistant biological indicator or a chemical indicator should be used to ensure that the autoclave cycle actually achieves sterilization. The indicator is placed in the area of a load least likely to reach sterilizing conditions. After the cycle is complete, examination of the indicator will confirm if conditions were sufficient for sterilization.

3.9.3 Centrifuges

Improperly used or maintained centrifuges can present significant health and safety hazards. A mechanical failure, especially of a rotor, can result in the release of flying objects, hazardous chemicals and/or biohazardous aerosols. Large amounts of aerosol can also be generated if a spill, leak or tube breakage occurs.

Guidelines for Safe Centrifuge Use:

- Check centrifuge tubes for stress lines, hairline cracks and chipped rims before use. Discard tubes with any of those conditions. Use unbreakable tubes whenever possible.

- Avoid overfilling tubes to the rim.
- Use proper caps or stoppers on centrifuge tubes.
- Take care to load the centrifuge so that it is properly balanced.
- Know the maximum rotor speed for the centrifuge and ensure that it is not exceeded.
- Do not open the lid during or immediately after operation. Allow the centrifuge time to fully stop.
- Promptly clean up all spills.
- Ensure that centrifuges are regularly cleaned and maintained.

3.10 Personal Protective Equipment (PPE) and Clothing

The use of protective equipment and clothing is a basic and mandatory precaution that people must always follow when working in Acadia's shops and laboratories. Basic protective equipment and clothing includes:

- protective eye wear - safety glasses with side shields, chemical goggles and, in some cases, face shields,
- appropriate clothing, lab coats and footwear, and
- protective gloves

Important note: Respirators are generally not approved for use in Acadia's shops and laboratories. See 3.10.4 for details.

3.10.1 Eye & Face Protection

Special Note - Contact Lens Wearers:

The risk of sustaining serious irreversible damage to the eye(s) is increased when contact lenses are worn in a laboratory. Some types of contact lenses may absorb airborne chemicals and transfer them to the eye. In cases of chemical exposure, contact lenses may hamper eyewash effectiveness or delay eye washing and/or medication being administered. For these reasons, it is recommended that contact lenses should not be worn in a laboratory.

Those who cannot avoid the wearing of contact lenses in a laboratory must make this known to their laboratory supervisor, and must follow these additional requirements:

- Inserting or removing contact lenses (except for removal in an emergency) is not permitted in laboratories. The health and safety risks posed by that are very high!
- The wearing of contact lenses in laboratories is permitted only when the hazards have been fully evaluated and found to be adequately controlled. Appropriate eye protection must be worn. For contact lens wearers, that should generally mean chemical splash goggles.

Safety Glasses

Many potentially serious eye injuries have been avoided simply by wearing safety glasses. For that reason, the wearing of safety glasses is mandatory in Acadia's laboratories and shops.

Safety glasses have lenses that are impact resistant and frames that are far stronger than standard glasses. Safety glasses also must have side protection.

Safety glasses should be worn whenever there is the possibility of objects striking the eye, such as particles, glass, or metal shards. Safety glasses come in a variety of fashionable styles to provide the best fit and comfort, including some designed to fit over prescription glasses. When selecting safety glasses, make sure that they meet a CSA standard.

Chemical Splash Goggles

Safety glasses may be adequate when the potential for splash is minimal, but **they do not provide adequate protection from significant chemical splashes.** They do not seal to the face, resulting in gaps at the top, bottom and sides, where chemicals may enter. Safety glasses are also not appropriate for dusts and powders, which can also get by the glasses.

Chemical splash goggles should be worn when there is potential for splash from a hazardous material. Goggles come in a variety of styles for maximum comfort and splash protection, and like safety glasses, goggles are impact resistant and must meet a CSA standard. Chemical splash goggles should have indirect ventilation so hazardous substances cannot drain into the eye area. Some are designed to be worn over prescription glasses.

Face Shields

Face shields are appropriate when working with large volumes of hazardous materials, either for protection from splash to the face or flying particles. **Face shields must be used in conjunction with safety glasses or goggles.**

3.10.2 Clothing, Lab Coats and Footwear

The risks of exposure must be assessed, and suitable clothing selected to protect against hazards encountered in labs and shops.

Lab coats are designed to protect the wearer from hazardous materials and to prevent the spread of chemicals and biologicals into places where food is served or people live. They should not be worn outside of laboratories.

The greatest risk to feet comes from dropping hot/cold, toxic, or corrosive agents on feet unprotected by proper shoes. Therefore, don't wear open toed shoes or sandals in the lab.

3.10.3 Protective Gloves

When skin contact with chemicals or potentially infectious materials is possible, faculty, staff and students should wear protective gloves. Disposable latex gloves are commonly used in Acadia's laboratories. As they are fairly resistant to tears and provide a good barrier to aqueous solutions, they have long been the glove material of choice in laboratories. Users must be aware, however, that latex gloves provide poor protection from many common chemicals which can penetrate latex and contaminate skin. In some cases, the chemical can pass through the latex without any visible deterioration of the gloves. An additional consideration is the allergic reactions to latex experienced by some.

Many suppliers sell alternatives to latex which offer much higher resistance to many of the chemicals. For many applications, gloves made of nitrile provide good resistance to chemical penetration. The following chart gives some qualitative information on the relative permeabilities of some glove materials to a few common chemicals. Always refer to the MSDS and manufacturers' recommendations for proper glove selection.

Butyl	- excellent resistance to gas and water vapour - resists aldehydes, ketones, esters, alcohols, dioxane and most inorganic acids and bases
Neoprene	- good protection from oils, alcohols, solvents and acids and bases
Nitrile	- good protection from aromatic, petroleum and chlorinated solvents, acids and bases - excellent puncture resistance
PVA (polyvinyl alcohol)	- coating is water soluble - resists ketones, aliphatic and aromatic solvents
Teflon	- impervious to most chemicals
Viton	- excellent resistance to chlorinated and aromatic solvents

Regardless of the choice of glove material, gloves should not be relied upon as the sole means of hand protection. Other protective measures should be taken to prevent or limit contact.

Guidelines for Using Protective Gloves:

- If gloves become contaminated, immediately wash the gloves and remove them if there is indication of deterioration.
- Remove gloves carefully, avoiding unnecessary direct contact with potentially contaminated areas of the glove.
- Remove and discard the gloves and wash your hands thoroughly following work in protective gloves.
- Do not handle telephones or other objects that others might handle without using gloves.
- Do not wear protective gloves in public areas of your building. That practice may put others at risk.

3.10.4 Respirators

Acadia does not generally authorize faculty, staff or students to use chemical or particulate respirators. A laboratory activity that might release a significant amount of a hazardous material must be carried out in a fume hood or biohazard cabinet, or controlled in some other fashion. A spill or leak that releases enough of a dangerous chemical to warrant the use of a respirator is generally too serious to be handled by untrained people. Such situations call for immediate building evacuation and response by a fully trained and properly equipped emergency response team.

Respirators are designed to protect people from harmful levels of contaminants in the air. Using a respirator in a dangerous atmosphere requires that:

- the user make the correct choice of respirator,
- the user know how to properly wear the respirator, and finally
- the respirator provide an air-tight fit around the user's face.

Failure in any of these areas could put the respirator user in serious danger. Because of the number of ways in which improper respirator use could actually endanger people, Acadia allows their use only in extraordinary circumstances, by only those who have been fully trained and who have been fit tested for the particular respirator.

If it is believed that other controls may not provide effective protection and that respirator use could be warranted in a particular situation, contact the Acadia Safety Office (1576). This must be done in advance of the need, so that proper respirator selection and training can occur.

3.11 Preventing Contact with Electricity:

- Visually inspect electrical equipment regularly. Remove damaged equipment from service and have it repaired.
- When handling electrical equipment, be especially cautious to avoid wet areas or contact with well-grounded fixtures (such as faucets or metal sinks).
- Report to Physical Plant Services when the operation of a piece of equipment trips circuit breakers or blows fuses.
- Do not use extension cords for anything other than very temporary installations (a maximum of thirty days).
- Never remove the third prong on electric plugs.
- Ensure that all electric equipment is approved by the Canadian Standards Association or similar certification body.
- Do not alter equipment or make electrical repairs unless you are competent to do so, and your supervisor has authorized the work.

3.12 Safe Handling and Disposal of Waste

Most laboratories and shops generate paper and other non-hazardous wastes that are handled in the same fashion as similar waste generated elsewhere on campus. Departmental offices can provide you with information on refuse collection and recycling programs in your building.

Many laboratories and shops also produce a variety of other wastes which cannot be discarded along with normal refuse. At Acadia, special practices are in place for the disposal of laboratory and shop wastes, including:

- chemicals and empty chemical containers,
- animal tissues,
- uncontaminated broken glass and other sharps,
- infectious or potentially infectious material and sharp instruments contaminated with blood or other contaminants,
- radioactive materials.

3.12.1 Chemicals and Empty Chemical Containers

As a general rule, chemicals may not be discarded with regular refuse or flushed down a drain. Improper disposal methods are an unacceptable risk to health and safety. Improper disposal can also cause environmental damage, and/or damage to the University's facilities. At Acadia, the details regarding disposal of surplus and waste laboratory chemicals is arranged through the various departments.

When research directions change or when projects are completed, chemicals are often left over. Although no longer needed in the original lab, sometimes researchers in other laboratories can use these chemicals. To avoid needless disposal costs and to save the costs of new chemical purchases, these surplus chemicals should be offered to other laboratories across our campus.

To reduce the likelihood of a laboratory fire, waste solvents must be regularly collected and disposed of. Laboratory and shop staff are responsible for moving waste solvents to a designated location in each building. In most cases, acceptable waste solvent containers are glass bottles which have a capacity of 5 L. or less. A properly completed Waste Solvent Tag must be attached to each container. The tag identifies the waste and its generator and provides the information needed to plan a safe and cost-effective disposal. More information on solvent disposal is available from your departmental Safety Officer.

All affected departments should dispose of other, nonsolvent wastes early each summer. In preparation for the collection, laboratory supervisors should assemble waste inventory information. That information should include:

- chemical name (abbreviations are not acceptable as one abbreviation can sometimes refer to several chemicals),
- volume of waste,
- type of container,
- age of chemical, if known,
- any unusual health, safety or environmental information that those dealing with the disposal may need to safely handle the disposal,
- the approximate composition of mixtures or solutions,
- the presence of water or halogenated components and the approximate concentration in waste solvents.

When the label does not provide a clear and unambiguous indication of the chemical composition, the material safety data sheet or some other source of information must accompany the inventory so proper disposal planning can proceed. Unknowns present a particular problem, as it is not possible to properly plan disposal without knowing the chemical, physical and toxicological properties of the waste. The disposal program is critically dependent on laboratories and shops maintaining good control of chemical inventories and ensuring that all chemicals are properly labelled.

Following collection, the work of preparing wastes for disposal begins. I some cases, solvents are redistilled and returned for reuse in University laboratories. If volumes do not warrant recovery or if the solvent is sufficiently contaminated to make recovery impractical, solvents are blended with other compatible wastes. The blended solvents are shipped to selected facilities.

Other non-solvent wastes are lab-packed and shipped to commercial chemical disposal facilities. Some non-hazardous chemicals may be disposed of locally. Solids, such a simple sugar, salt and other non-toxic and environmentally benign chemicals, may safely be disposed of in regular garbage. Such chemicals should be securely bagged and labelled as "NON-HAZARDOUS WASTE". The label should be dated and signed by the person authorizing the disposal.

In a similar fashion, aqueous solutions of some non-hazardous water soluble chemicals may be flushed to a sewer. No material with a pH below 4 or above 11 may be flushed down the drain. Nor may flammable materials be disposed of in this manner. If you have any doubt about the appropriateness of disposing of any chemical by flushing down a drain or placing it with regular trash, contact the departmental Safety Officer for advice.

Empty chemical containers must be cleaned of chemical residue and labels removed or defaced prior to disposal. When a chemical may have migrated into a plastic container and it may be difficult to completely clean the container, it is prudent to puncture the container to render it useless for reuse.

It is possible to recycle some thoroughly cleaned glass containers.

3.12.2 Waste Animal Tissue

All animal anatomical materials must be packaged to prevent leakage and stored refrigerated or frozen while awaiting disposal. Acadia's Biology Department arranges for the collection and disposal of waste animal tissue by incineration.

Animal tissue that is contaminated with radioisotopes or sharps should be treated as a radioactive or sharps waste. Animal tissue that presents other, more unusual hazards should be handled in accord with instructions from the departmental Safety Officer.

3.12.3 Radioactive Materials

For instructions on disposal of radioactive waste, see **Acadia's Radiation Safety Policy & Procedures Manual.**

3.12.4 Broken Glass and Other Sharps

Uncontaminated broken glass and other sharp materials must be packaged in sturdy, puncture-resistant containers to protect custodians and other refuse handlers. The container must be labelled as "SHARPS - HANDLE WITH CARE". These wastes may then be deposited directly into the general garbage receptacles serving your building.

"Medical sharps" (needles, lancets, scalpel blades, etc) and all sharps that are contaminated with chemicals or are potentially infectious must be placed in an approved sharps container. Once they are approximately 2/3 full, the sharps containers are collected and disposed of through Physical Plant Services (call 1176 to arrange pick-up).

3.12.5 Potentially Infectious Bio-medical Waste

All waste that might contain a pathogen must be handled in a way that minimizes the risk of infection. Follow the Laboratory Supervisor's directions and use protective equipment as necessary. Acadia has arranged for suitable disposal through an approved facility. Special bags and boxes are available for use by contacting Physical Plant Services (1176). They should only be filled to approximately 50 – 75% of capacity. As long as it does not pose a hazard to building occupants, a small amount of this waste may be stored locally, awaiting pick-up.

Local autoclaving is another method of rendering potentially infectious waste non-infectious. Autoclaving involves treating the waste with high pressure steam for a sufficient period of time to kill any pathogen that might be present. Remember that autoclaving can drive volatile chemicals from waste and expose building occupants to toxic chemicals. For example, one should not autoclave wastes containing phenol unless there is provision for capturing and venting the phenol vapours that might be emitted during the autoclaving cycle or when the autoclave door is opened.

It is normally acceptable to dispose of autoclaved wastes along with regular trash. Following treatment in an autoclave, waste should be placed in a second bag or other container.

3.13 Laboratory and Shop Inspections

Formal inspections are an important part of any safety program. Regularly scheduled inspections complement the much less formal "inspections" that faculty, staff and students should do each time they enter the laboratory or shop.

A formal laboratory or shop inspection is normally carried out by the supervisor. Members of Acadia's Sciences Health & Safety Sub-committee may also take part, or may perform a random inspection as an audit function.

The purpose of an inspection is two-fold:

- to survey the physical facility in order to identify conditions which could lead to an injury, illness, or other loss, and
- to observe work methods, practices, and behaviours that could lead to an injury, illness, or other loss.

Having identified a concern, the inspection also includes a recommendation for corrective action.

By documenting the inspection and the follow-up, laboratory and shop supervisors demonstrate their commitment to health and safety. Although there are many ways to carry out effective inspections, many people feel that using a good inspection checklist reduces the chances of overlooking a possibly serious problem. A general

Laboratory and Shop Inspection Checklist is provided on Acadia's Health & Safety Website, for local printing.

3.13.1 Laboratory and Shop Inspection Procedures

1. Department Heads must ensure that each laboratory and shop is formally inspected **at least monthly**.
2. Laboratory and shop inspections are generally the responsibility of the supervisor. For laboratories or shops where a specific supervisor is not clearly established, the respective Department Head shall assign responsibility for formal monthly inspections.
3. The supervisor or a competent delegate shall complete the Laboratory and Shop Inspection Checklist. If a more appropriate checklist is available, it may be used instead. Immediate action should be taken to control hazards that pose imminent danger. Deficiencies and opportunities to improve health and safety should be noted on the back (page 2) of the checklist. In many cases, the supervisor can determine and implement the appropriate corrective actions. This is especially true for hazards related to practices and behaviours. Corrective actions taken should also be recorded on the back of the checklist.
4. Completed checklists must be submitted to the Department Head for review and action on any outstanding deficiencies/opportunities. The laboratory or shop supervisor should work closely with the Department Head to ensure that deficiencies/opportunities are clearly understood, and that effective, reliable corrective actions are identified and are implemented.
5. The Department Head must ensure that corrective actions are documented and are followed-up. Once all actions are complete, the Department Head must ensure that all checklists are locally archived for future reference.

3.14 Summary – Preventing Harm & Other Loss

Although the specifics of preventing harm and other loss in a lab or shop setting can be very complex, the fundamentals are simple:

1. Anticipate and recognize hazards,
2. Evaluate the risks of hazard exposure to yourself, to others around you, and to the University's facilities. Consider the likelihood and the consequences.
3. Control the hazards by applying the principles described in the Hierarchy of Control.
4. Observe and comply with this Lab and Shop Safety Program.
5. Communicate and work together!

4. RESPONDING TO EMERGENCIES

Prompt and effective response to an emergency can be the key to preventing injury, illness and property damage.

4.1 Responding To a Fire

Upon discovering a fire, the first step is to sound the fire alarm to warn building occupants to begin evacuating. The fire department is usually able to respond to campus emergencies within a very few minutes. So, with professional help only minutes away, Acadia's practice is to:

- evacuate buildings;
- care for injured people and others who might be unable to evacuate without assistance; and
- leave the fire fighting to trained fire fighters.

4.1.1 If You Discover a Fire

- **Sound the alarm** by tripping a manual pull station while exiting.
- **Evacuate** the building in an orderly manner, to a designated safe holding area away from the building and fire lanes;
- **DO NOT USE ANY ELEVATOR;**
- Report the fire by calling **7-911** from a safe location;
- **Give** the building name and location of the fire;
- Report the fire to Safety & Security by calling **585-1103**; if safe to do so;
- **If corridors are smoke filled** and exiting is dangerous, **find safe shelter** and
- contact Security by dialing **585-1103**, advising of your location;
- **If special assistance** is required to evacuate the building due to physical limitations, find safe shelter and contact Safety & Security by dialing **585-1103**, advising of your location and condition.

4.1.2 Responding to a Fume Hood Fire

The hood is the best place to have a spill, release, or fire. Do your best to keep it localized there. Here is what you should do in the event of fire in a hood:

- If you can do it safety, shut off utilities (gas, etc.) supplied to the hood. Do not put yourself at risk to do this!
- Immediately close the sash all the way.
- Keep the fume hood exhaust on at all times. If "emergency" exhaust button is available on hood, push to activate.

- Use your judgment about magnitude of the fire. If there is any chance that it may escalate out of control, follow the procedure above ("If You Discover a Fire").

4.1.3 Using a Portable Fire Extinguisher

Caution: Portable extinguishers must be used only in controlled conditions. See **Using Portable Extinguishers** for precautions and instructions for safe extinguisher use.

4.1.4 If Your Clothing is on Fire

- If your clothing is on fire (and the floor is not), **STOP, DROP and ROLL** on the floor to extinguish the flames.
- If you are **within a few feet** of a safety shower or fire blanket, you can use these instead, but resist the impulse to run any distance if you are on fire.

4.2 Responding to Chemical Spills

All laboratory and shop faculty, staff and students should be prepared to respond to chemical spills. Planning ahead and equipping the laboratory with the required equipment usually ensures a quick, safe and effective response.

Effective spill response requires knowledge of the physical, chemical and toxicological properties of spilled chemicals. When a spill occurs, laboratory occupants must immediately assess the situation to see if the spill has created a serious or even life-threatening situation requiring an immediate building evacuation. A spill of a few millilitres of a particular solvent many not present a major hazard. But a spill of an appreciable volume of a flammable liquid might call for a building evacuation. For example, a spill of 4 L of a volatile, flammable liquid in a small room might well produce vapour levels in the flammable range. A spark, a flame or even a hot surface could cause a fire that might engulf the room. A total evacuation might also be required in the event of a leak of an appreciable quantity of a flammable or toxic gas.

Departments are responsible for assembling and maintaining spill kits which contain absorbents, protective equipment and a selection of small tools for use in responding to <u>small</u> chemical spills. All faculty, staff and students working in laboratories and shops must be made aware of the location of these spill kits, their contents, and how to use them.

4.2.1 Responding to Significant Spills or Leaks

If a spill or leak is significant and there is risk of fire, explosion or toxic levels of airborne contamination:

- evacuate the area, closing the door behind you,

- sound the building alarm and leave the building,
- move 100 meters from the building and meet Safety & Security or Fire Department personnel to provide information on the nature of the emergency,
- re-enter the building only when Safety & Security declares it safe to do so.
- notify Acadia's Safety Office at 585-1576.

4.2.2 Responding to Minor Spills or Leaks

If you have assessed the risks and you feel confident of your ability to deal with the spill and you are certain that you and others in the building are not in danger:

- contain the spill,
- if spilled material is combustible, remove sources of ignition,
- call Safety & Security at 585-1103, giving your name, the nature of location of spill, and your intended action,
- begin clean-up, using appropriate protective clothing and equipment.
- contact the departmental Safety Officer or the Health & Safety Office (585-1576) regarding the disposal of contaminated waste.

4.2.3 Specific Spill Responses

- **For Spills of Acids,** neutralize the spill carefully using soda ash (sodium carbonate).
- **For Spills of Bases,** neutralize the spill carefully. Dilute with water and neutralize with dilute acid.
- **For Spills of Oxidizers,** remove any readily oxidizable materials from the area of the spill. Destroy the oxidizer by carefully adding sodium bisulfite solution.
- **For Spills of Potentially Infectious Material,** treat the spill with a dilute solution of household bleach and allow to stand for 10 minutes. Prepare the bleach solution by a 10-fold dilution of household bleach with water

4.3 First Aid Response

Acadia University is well served by the nearby emergency room at the Eastern Kings Memorial Health Centre, and by emergency response paramedics and first responders. Our primary approach to first aid focuses on dealing with life-threatening conditions and arranging for medical assistance. Although medical help is usually available within a matter of minutes, the person providing first aid needs to be ready to render life-saving help. Where the victim is not in immediate danger, the first aid provider must be cautious not to unwittingly make injuries worse.

In responding to any injury, the first aid provider should first quickly assess the situation to ensure that, in trying to help, he or she is not at risk. A toxic air contaminant and an electrical hazard are only two of the hazards that might influence if or how a first aid provider can safely respond to a victim. Although many minor injuries can await the arrival of medical assistance, some require immediate action. If a person is bleeding excessively or has stopped breathing, delayed first aid could prove fatal. Similarly, delay in responding to a splash or spill of a corrosive chemical could result in permanent skin or eye damage.

4.3.1 First Aid for General Chemical Contact

A spill, a splash or an explosion that gets a chemical on someone's clothing, skin or in their eyes is an occurrence that requires an immediate response. Corrosives, including the mineral acids, bases and many strong oxidizers, begin to damage skin immediately. Other chemicals can even be absorbed in harmful quantities through unbroken skin. In some cases, skin contact with harmful chemicals does not cause pain. The victim may not appreciate the seriousness of the situation. When any of these chemicals contaminate clothing or the skin, or get in the eye, prompt first aid is essential. Contaminated clothing should be removed immediately and the affected area flushed with large amounts of water. When a significant portion of the body is contaminated, an emergency shower is the only practical means to completely wash away the chemical.

To Use An Emergency (Deluge) Shower:

- Step under the shower.
- Pull the cord to activate the shower.
- Remove contaminated clothing.
- Shower for at least 15 minutes.
- Seek medical assistance.
- Be prepared to provide the ambulance attendants or other medical personnel with information on the chemical involved.

In most cases, trying to "neutralize" the contaminant, by applying a second chemical, increases rather than decreases the risk of harm. Nor should fluids other than water be used. Even with contaminants that are poorly water soluble, flowing water is generally preferred. Other solvents should generally not be used for flushing; they may actually aid the absorption of the contaminant through the skin. Phenol, for example, is quite a dangerous chemical. It is readily absorbed through the skin and it acts as a local anesthetic so skin contact is not initially painful. There is a widespread misconception that alcohol should be used to wash phenol from the skin. However, using alcohol to wash skin could actually aid in the absorption of phenol and increase the severity of an occurrence. For even minor occurrences with phenol, flush the affected area thoroughly with water only.

4.3.2 Responding to Eye Emergencies

Because chemical damage to the eye often begins almost immediately, it is essential to respond quickly to an eye contact with a chemical. Here again, the appropriate response is immediate and thorough flushing with water. Faculty, staff and students in Acadia's laboratories and shops have ready access to eye wash stations for use if there is eye contamination. Everyone should be familiarized with the location and operation of eye wash stations and emergency showers as part of an initial laboratory or shop orientation.

To Use an Eye Wash Station:

- Turn on the water.
- Adjust the proportion of hot and cold water (if those controls are available) to provide a comfortable temperature.
- Hold eye lids open, being careful not to introduce foreign material into the eyes.
- Flush eye for a full 15 minutes.
- Seek medical assistance.
- Be prepared to provide the ambulance attendants or other medical personnel with information on the chemical involved.

4.3.3 Responding to Chemical Ingestion

Although unintended ingestion of chemicals is rare in laboratories or shops, first aid might be needed. Historically, the most common reasons for chemical ingestion were the consumption of food or beverages in the laboratory and pipetting by mouth. These practices are not permitted in Acadia's laboratories or shops.

In Cases of Chemical Ingestion:

- Have someone call an ambulance (7-911 from on campus 585 extensions).
- Have someone call Acadia Safety & Security at local 1103. Give the location and nature of the situation.
- Have the victim rinse his or her mouth with large amounts of water while avoiding swallowing the water.
- Keep the victim comfortable and calm while awaiting the ambulance.
- Be prepared to provide the ambulance attendants with information on the chemical involved.

Contrary to popular belief, there are very few antidotes for particular chemicals. In most chemical poisoning cases, medical treatment involves supportive care rather than the use of antidotes. Inorganic cyanides and hydrogen fluoride (or hydrofluoric acid) are two exceptions in that antidotes may be effective in treating a poisoning. Laboratories frequently using these or other chemicals with high acute toxicities should research the feasibility of maintaining antidotes readily available. Note that antidotes must only be administered by medical doctors or under the direction of other qualified medical personnel (including poison control specialists accessed through 911).