Dalhousie
University

Laboratory Safety Handbook

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Laboratories are potentially dangerous places. Chemical and physical hazards are present and a lack of knowledge or a moment's inattention could lead to an injury. To reduce the likelihood of laboratory accidents, Dalhousie University has adopted a Chemical Safety Plan. The Plan includes a set of safety policies and procedures that were developed by a Committee appointed by the Deans of Dentistry, Health Professions, Medicine and Science. These policies underpin this manual that is intended to provide basic information and advice on laboratory safety to staff and students in Dalhousie research laboratories.

The manual deals primarily with chemicals and does not deal in any depth with the other laboratory hazards such as:

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

The manual compliments the laboratory safety training program. It provides an overview of the chemical laboratory safety practices that are required in Dalhousie University research laboratories. The manual is by no means comprehensive. Laboratory supervisors, staff and students will need to consult material safety data sheets and other documents to develop adequate safe work practices.

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.

APPENDIX

1. THE LEGAL FRAMEWORK

Dalhousie's safety policies aim to provide a safe and healthful environment that adequately supports work and study. But people in laboratories also need to be aware of the complex web of laws and regulations that place special responsibilities on people in laboratories.

1.1 Occupational Health and Safety

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

T chemicals be labelled,
T material safety data sheets be available to those who use chemicals, and that
T people who work with 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. Provincial and municipal agencies administer the Codes and officers from these agencies regularly inspect Dalhousie buildings. In some highly specific areas, regulatory agencies use guidelines and codes developed by such foreign agencies as the US National Fire Protection Association.

1.4 Transportation of Chemicals

Whenever dangerous goods are transported by road, rail, air or sea the federal Transportation of Dangerous Goods Act applies. It requires the shipper to classify, label and package chemicals, and place a dangerous goods placard on the vehicle that will transport them. It also requires receivers to maintain records of shipments received. The regulations specify that shippers or receivers of dangerous goods must receive periodic training.

For chemicals coming into Dalhousie laboratories, the supplier and departmental storekeepers handle much of the work related to the Transport of 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 Act still applies. 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 Act.

1.5 Other Legislation

Other Federal and Provincial legislation affect some Dalhousie laboratories. Some years ago, the Nuclear Safety and Control Act established a system under which the University is granted a licence under which laboratories use radioisotopes and radiation emitting equipment. Other regulations apply to areas such as the use and storage of alcohol, drugs and infectious agents and the health of laboratory animals.

1.6 Responsibilities

To provide a safe and healthful laboratory, Dalhousie relies upon the people who work in these laboratories. People who are aware of their responsibilities and who discharge them carefully are critical to a successful safety effort.

Directors, Chairs and Heads of Departments

are responsible for ensuring that the appropriate policies and procedures are in place so that their unit's programs comply with University policy, health, safety and environmental legislation.

Laboratory Supervisors

are responsible for ensuring that activities undertaken in their laboratories are consistent with the Dalhousie University policy of providing a safe and healthful environment for staff and students and for those who provide services to their laboratories. In discharging these responsibilities, laboratory supervisors shall ensure that:

T their laboratory complies with University policies, and

T staff and students are properly instructed in and observe safe laboratory practices.

Laboratory 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 procedures and the supervisor's instructions.

1.7 Safety Committees

Dalhousie Environmental Health and Safety Committee

As required by Nova Scotia's Occupational Health and Safety Act, the University established the Dalhousie University Health and Safety Committee. This Committee meets regularly to provide a forum to discuss environmental health and safety concerns. The Committee also plays a key role in engaging the members of the University to assist the University in achieving the highest possible standard of safety. Committee members represent the University's employee groups, the University and the Student Union. Members of the Safety Office can provide additional information on the Committee.

Faculty, Building or Departmental Safety Committees

University policy encourages heads of units to establish local health and safety committees. These committees provide advice to the head of the unit and assist in dealing with local health and safety matters. Your departmental office can help you contact your local committee.

2. HAZARDS OF CHEMICALS

2.1 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 a chemical 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.

2.1.1 Dose

The 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. But, as the body is capable of repairing the damage that may have been done, the exposure in this range is without adverse consequences. At still higher doses, the intense exposure overwhelms the defense mechanisms causing irreversible damage. Finally, at even higher doses, the exposure can be fatal.

Figure 2.1

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that, for example which there is
no cancer risk. Th risk although
it is well establish creasing dose.

2.1.2 Routes of

Chemical exposure 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, particulates or finely divided liquid droplets. Inhaled chemicals can damage the nasal passages and the upper and lower regions of the respiratory tract. Contaminants - particularly fine particles - may be deposited in the lung where they can cause damage. Or the inhaled contaminants may be absorbed through the lung. The blood stream can then transport the absorbed contaminants to other parts of the body.

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 dimethyl sulfoxide, can even pass through intact skin. Of even more concern is the fact that a small number of chemicals (Dimethyl sulfoxide is perhaps the best known example) can transport dissolved chemicals across intact skin leading to exposure to chemicals that would not normally penetrate the skin. Once such chemicals penetrate the skin the blood stream can again transport them to organs well removed from the site of absorption.

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

2.1.3 Duration of Exposure

A chemical exposure can be of short duration as might occur during an accident or a spill. Under such circumstances the exposure might be reasonably intense. Such short, intense exposures are termed *acute exposures*. 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 exposure 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. And it is particularly difficult 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 - particularly with respect to low level, long term exposure-prudence suggests minimizing exposure to the extent possible. Minimization of exposure is particularly important when the chemical is a 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 poorly known. Minimizing exposure is doubly important in such cases.

2.1.4 Chemical Elimination

Following chemical uptake by ingestion, inhalation or by absorbtion 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 and the resulting simpler chemicals 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 handled directly, the body must often first metabolize non-food chemicals. The simpler chemicals produced by this metabolism are also excreted again, often in urine.

However, the body is unable to effectively metabolize 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. And many 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 di-isocyanate** and many **related isocyanates**.

Effects on the Central Nervous System

Many chemicals, including most common solvents, act on the human central nervous system (CNS). 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 Specific Organs

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 breathing.

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.

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.

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.

Blood

Carbon monoxide and cyanide anions are species that 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 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 rare cancer of the membrane which 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. Much more information is available in the monographs that IARC publishes as part of each evaluation. IARC also presents a complete list of evaluated chemicals at: **http://www.iarc.fr/** - select "Databases".

Table 2.1

Some Selected Chemicals Evaluated by IARC

Group 1 Chemicals which are Carcinogenic to Humans:

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

Group 2a Chemicals which are Probably Carcinogenic to Humans:

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

Group 2b Chemicals which are Possibly Carcinogenic to Humans:

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

California also has an extensive electronic list of carcinogens and reproductive toxins available at the State's environmental agency's web site. The list - known as the Proposition 65 List - is used in connection with the Californian safe drinking water legislation.

2.1.6 Preventing Chemical Poisoning

People must be exposed to a chemical in order for it to do any harm to them. So a properly stored chemical does not create any exposure and thus cannot cause harm. Thus avoiding adverse health effects simply requires control of exposure to chemicals. Substituting a less hazardous chemical for one that presents a greater danger is one way to reduce the possibility of harm. Replacing solvent-based scintillation fluids with those that are water-based and replacing chromium based glassware cleaner with detergents, are two examples of substitutions that have been adopted in many Dalhousie laboratories.

If safer chemicals cannot be used, then administrative means can be used to reduce risks. Reducing chemical inventories is one approach. You can't have an accident with a chemical that you don't have in the laboratory. Similarly, storing smaller volumes of essential chemicals reduces the chances that an accident will involve enough chemical to do serious harm. The University's solvent storage policies try to reduce the fire hazard, in part, by limiting the quantities of solvents in laboratories. Dilution is another approach that can reduce risks. For instance, the corrosivity of mineral acids and the oxidation potential of oxidizers are related to concentration. It is sometimes possible to prepare more dilute reagent and stock solutions. In an accident or a spill, these more dilute solutions often present a much reduced hazard.

Ensuring they have access to material safety data sheets and other information on the physical, chemical and toxicological properties of the chemicals they use, enables laboratory staff and students to work safely. Providing the required instruction, facilities and equipment gives them the tools they need to do their work safely.

Finally, preventing harmful chemical exposure requires following the appropriate laboratory practices, many of which are dealt with elsewhere in this manual. Good science requires that you carefully plan all experiments. And safety is as important as any other aspect of the experimental design.

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.

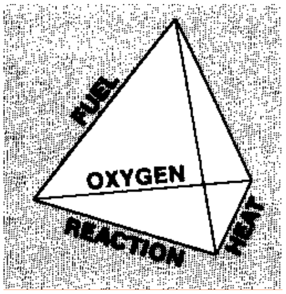
2.2 Flammability

As many common laboratory chemicals burn, fire is a major laboratory 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 focusses on the fire risk presented by organic liquids and gases. Although these liquids are serious fire hazards, laboratory staff and students should not overlook the fact that ordinary combustibles such a paper, and wooden furniture also burn. A fire in a laboratory, whether it involves ordinary combustible 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 2.2 Fire Tetrahedron

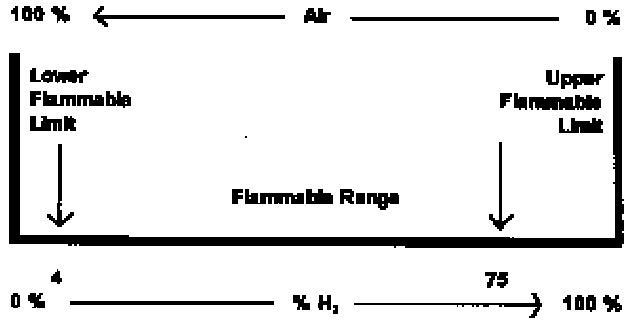


2.2.2 The Flammable Limits

Although the principles are the same for both solids or liquids, laboratory 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. The diagram 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 spark or flame could start a fire.

Figure 2.3



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.

Table 2.3 **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

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 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 flammable liquids.

Table 2.4

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

2.2.4 Preventing Fires

Preventing fires normally involves preventing the accumulation of ignitable vapours and avoiding ignition sources.

To Prevent Accumulations of Ignitable Vapours:

T Minimize volumes of flammable liquids in the laboratory.
T Keep flammable liquids tightly capped.
T Use flammable liquids only in fume hoods.

To Prevent Contact with Sources of Ignition:

T Avoid using flames near flammable liquids.
T Ground and bond containers to prevent accumulation of static electricity while dispensing of flammable liquids from bulk containers.
T Keep electrical equipment in good repair and away from flammable materials.
T Don't store flammable liquids in domestic refrigerators or freezers.
T Store and use oxidizers away from flammable liquids and gases.

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.

2.3 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 accidents in university laboratories. Because an unexpectedly dangerous reaction can have very serious results, laboratory staff and students need to understand the hazards. Even when the hazards are well known, accidents happen. Most laboratory staff 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.

2.3.1 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

2.3.2 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.

Peroxide-Forming Chemicals

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 a Dalhousie 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.

To Reduce the Chances of Peroxide Accidents:

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

T Test* containers for peroxides at least monthly and record date and result of test. If test shows the presence of significant amounts of peroxide remove the peroxide or contact the Safety Office for advice on disposal.
T Treat any peroxide-forming chemical as an extreme shock sensitive explosion hazard unless you are sure it is free of peroxides.
T Do not move the container if crystalline deposits or viscous liquids form in peroxide-forming chemicals. Call the Safety Office for help.

** Test for Peroxides in Ethers:*

T Use commercial peroxide test strips, or

T Add 9 ml. of ether to 1 ml. of a saturated solution of KI. Mix carefully. A yellow colour indicates the presence of peroxides.

Table 2.5

Some Common Peroxide-Forming Chemicals:

acetal
dibutyl ether
1,4-dioxane
isopropyl ether
cyclohexene
diethyl ether
ethylene glycol dimethyl ether
tetrahydrofuran

Some Less Common Peroxide-Forming Chemicals:

decahydronaphthalene
dicyclopentadiene
methyl acetylene
tetrahydronaphthalene
vinyl ether
diacetylene
divinyl acetylene
sodium amide
vinyl acetate
vinylidene chloride

2.3.3 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.

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 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 accidents. Several years ago, an accidental 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.

To Avoid Unexpected Reaction Hazards:

T 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.
T Always observe precautions outlined on the MSDS when working with an explosive or dangerously reactive compound.
T 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.
T Consider using an explosion shield, a face shield or safety goggles in addition to usual protective equipment and clothing.
T Never mix incompatible chemicals without taking precautions to protect yourself and others in the laboratory.

Although by no means exhaustive, the following table provides information on some of the more common incompatibilities. The Material Safety Data Sheet should always be consulted before mixing chemicals.

Additional Reading:

1. Bretherick L., **Handbook of Reactive Chemical Hazards, 4th ed.**, Butterworth - Heinemann,Oxford, Boston.1990

2. Yasida T., **Safety of Reactive Chemicals (Industrial Safety Series)**, Elsevier Science Publications, Amsterdam, 1987.

SOME 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.

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 - Acids, carbon disulfide, heavy metal salts
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) - Oxidizing agents
(in air, some are spontaneously combustible)
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 - Reducing agents
(some peroxides are shock sensitive)
Phosphorus pentoxide - Alcohols, bases, water
Sulfuric acid - Alcohols, bases, chlorates, perchlorates, permanganates, water

There are many other hazardous chemical combinations.

2.4 Environmental Impacts of Chemicals

Although the analogy does not work well in every respect, there are some striking parallels in the way that chemicals impact both human health and the environment.

Environmental systems can often cope with the release of a chemicals or chemical mixture provided the quantity of chemicals involved is reasonably small. But once the quantity rises above these no-effect levels, environmental damage begins to occur. Chemicals released into the environment can do local damage, harming plant or animals in a manner analogous to the damage that some chemicals can do to people at the site of contact. And, in just the same manner that transportation mechanisms allow chemicals to be moved to locations in the body removed from the site of first contact, transportation mechanism also allow chemicals to move from place to place in the environment. Surface water, ground water and atmospheric transport are all effective ways of moving chemicals from place to place and even around the globe. So effective are these transportation mechanisms that traces of industrial pollutants can be found in polar ice masses thousands of miles from the industrial and commercial sites from which they were released.

Just as the human body is able to metabolize some chemicals to produce other, more simple compounds, environmental systems are also able to transform some chemicals that are released into the environment. Plants, animals and other living components or ecosystems are often able to change chemicals that are released into the environment. Composting and natural decay are clearly examples of nature's way of reducing complex materials into simpler, often reusable, ones. Some chemicals are also broken down by natural chemical and physical processes. The resulting chemicals are often - but not always - less harmful than the parent compound.

But nature is not able to efficiently break down all chemicals. Modern industrial society has learned to make synthetic chemicals which have no counterparts in nature. For many of these, natural breakdown mechanisms do not exist. Without a means to destroy these chemicals, their release into the environment leads to accumulation usually in specific pockets of the environment. For example, DDT, mirex and some related fat-soluble and persistent pesticides have accumulated in animals at the upper end of the food chain to the point that the survival of some species has been endangered. This accumulation of chemicals can occur in humans as a result of either environmental or work-related exposure.

Some chemicals impact on the entire planet in ways which do not have good parallels in the effects that chemicals have on people. For example, complex chemical reactions take place in the atmosphere to convert sulphur dioxide to water soluble compounds. Prevailing winds can carry these acidic emissions for thousands of miles before precipitation returns the acidic contaminant to ground. In places where soil does not have the capacity to buffer this acid input, serious environmental damage can - and has - occurred. Similarly chemical and physical/chemical processes convert the chemicals in engine exhaust into smog. Again, atmospheric transport can carry this material far from the site of production where it can harm both people and vegetation. We now know that fluorochlorocarbons undergo chemical reactions in the earth's upper atmosphere and that these reactions consume ozone which forms atmospheric layer that shields the earth for harmful solar ultraviolet radiation. Life on the planet has evolved beneath this protective ozone blanket. The threat to human and other forms of life by the destruction of the ozone layer has prompted governments to create regulations that seek to remove these chemicals from commerce and limit the continued release of these chemicals.

Human and natural activity release millions of tonnes of carbon dioxide annually into the atmosphere. These releases are thought by some to be slowly increasing the concentration of the gas in the atmosphere. Carbon dioxide (and methane and nitrous oxide among other gases) are green house gases. Sophisticated computer models suggest that increasing CO_2 levels change the way in which some incoming sunlight is re-radiated back into space. Without these re-radiation losses the models predict rise in global temperature, which in turn could cause the polar ice caps to melt and dramatically alter climate. Carbon dioxide is stable so there are no natural mechanisms that will convert it to another chemical. Instead, for millennia, nature has deposited carbon dioxide in vegetation, in sea water and coral reefs. The concern is that cutting forests over large areas of the plant's surface and unrestrained emission of green house gases will work together to set in motion catastrophic climate change.

As an institution, Dalhousie is larger than many Nova Scotia towns. As such the University's consumption of water, fuel, power and a host of other consumables come with an environmental cost. But the use of chemicals in the University's laboratories presents a more unusual threat to the environment.

Research laboratories rarely use chemicals in any significant quantity - at least by industrial standards. To the extent that small quantities of chemicals usually afford a smaller risk to the environment, Dalhousie laboratories might not be seen as being a significant environmental risk. But, together, the laboratories annually use thousands of kilograms of chemicals, some of which are environmentally hazardous. Inappropriate disposal of these chemicals and other laboratory waste along with regular trash, or by flushing them down the sewer, could cause environmental problems.

Selecting an appropriate disposal technique requires a knowledge of the physical, chemical and toxicology properties of the chemical. A discussion of the disposal options for the thousands of chemicals used in Dalhousie laboratories is beyond the scope of this manual. Laboratory staff and students should normally discard waste and surplus chemicals through the University's disposal program. For information of the program or for advice on disposing on individual chemicals contact the Safety Office.

3. OTHER LABORATORY HAZARDS

3.1 Electrical Hazards

Laboratories are full of complex equipment. If it is improperly maintained or worn out, this equipment can pose a safety hazard. Although some hazards, such as frayed electrical wires and damaged plugs, are not unique to laboratories, they are serious hazards. Typical laboratory 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 laboratory electrical equipment carries enough electrical 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 metallic surface of a tool or an appliance. Touching the metallic 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 standing directly on the ground or in contact with water or plumbing which in turn in connected to ground.

To prevent such accidents, most recently constructed homes have ground fault circuit interrupters (GFCIs) installed on outlets in washrooms, laundry rooms, kitchens and near water faucets. Dalhousie has installed GFCIs in the electrical panels of circuits serving laboratories.

A GFCI is sensitive to leakage of very small currents. When it detects leakage, a GFCI interrupts the flow of current. Because they react in less than 1/40th of a second, a GFCI deactivates the circuit before a person can be harmed by the ground fault. If you have any concerns about the electrical safety of your laboratory or any laboratory equipment speak to your supervisor or call the Safety Office or Facilities Management.

To Prevent Contact with Electricity:

T Inspect electrical equipment regularly. Remove damaged equipment from service and have it repaired.
T Report to Facilities Management when the operation of a piece of equipment trips circuit breakers or blows fuses.
T Do not use extension cords for anything other than very temporary installations. Do not remove the third prong on electric plugs
T Ensure that all electric equipment is approved by the Canadian Standards Association or similar certification body.
T Do not alter equipment or make electrical repairs unless your supervisor has authorized the work.

Additional Reading:

1. **An Illustrated Guide to Electrical Safety, 2nd ed.**, Greenwald editor, American Society of Safety Engineers, Des Plaines, IL,1993.

3.2 Mechanical Hazards

Mechanical hazards are also present in laboratories. 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.

Laboratory staff 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 operation where the employees have years of training and experience. No one may operate power equipment in any Dalhousie workshop unless trained and authorized to do so by the laboratory or workshop supervisor.

To Avoid Workshop Accidents:

T Only use shop equipment that you have been trained to operate.
T Don't work alone. Always ensure that someone else is present to help in the event of an accident
T Never operate equipment without all guards and safety devices in place.
T Always use safety eye wear and other protective equipment as specified in the workshop's safety program.
T Exercise extreme caution when using saws and other equipment with rapidly rotating blades.

Pressure is another form of mechanical energy which can be released suddenly. Equipment that operates above or below atmospheric pressure, can explode or implode with alarming results.

To Avoid Injuries with Pressurized Apparatus:

T 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.

T Post notices to warn others of the danger of pressurized equipment.

T When setting up distillation or similar apparatus, double check to ensure that you are not inadvertently about to heat a closed system.

3.3 Extremes of Temperature

Many operations and many pieces of equipment found in laboratories operate at a high temperature, presenting risk of burns and fire. Planning work in advance and attention to work in progress are normally sufficient to prevent accidents. Ensuring that insulation is undamaged and that equipment is maintained are important parts of a burn prevention program.

Some laboratory activity involves the use of very high temperatures or equipment that runs very hot. Glass blowing, high temperature pyrolysis and plasma research are examples of these very high temperature activities. Laboratories involved in very high temperature activities should carefully review their practices to ensure they do not place staff, students or other building occupants at risk. The advice of a departmental safety committee, the Safety Office and perhaps the Fire Department should be sought.

Very low temperature experiments are common in some laboratories. Direct skin contact with a very cold surface or coolant burns skin in a fashion quite like heat. The potential for harm increases as the further the temperature is from room temperature. The very cold cryogenic liquids (liquid nitrogen, liquid oxygen and liquid helium) well as dry ice (solid carbon dioxide) can all do immediate damage to exposed skin on contact. People who work with these materials need to be continually aware of the potential for an accident. They need to follow the proper procedures when dispensing these chemicals, particularly the liquids, and wear the appropriate protective gloves, face shields and other protective equipment.

Cryogenic liquids and dry ice present several other hazards as well. Evaporation (or sublimation) release very large volumes of gas. 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.

Liquid oxygen presents a particular hazard. Evaporation enriches rather than depletes the oxygen content of the air of a room. Enriched oxygen atmospheres can create extreme fire hazards. Similar situations could develop if oxygen were to leak into a confined space from a compressed gas cylinder. 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 Dalhousie laboratories. But in view of the possibility of a serious accident, supervisors in any Dalhousie laboratory planning to use liquid oxygen, must review the project beforehand with the Safety Office.

4. RESPONDING TO LABORATORY EMERGENCIES

4.1 Responding To a Fire

4.1.1 Initial Response

Prompt response to a fire is the key to preventing injury and property damage. The primary consideration is to prevent injury. upon discovering a fire, the first step is to sound the fire alarm to warn building occupants to begin evacuating. Pulling a fire alarm in Dalhousie buildings automatically initiates a call to the fire department. The fire department is usually able to respond to campus emergencies within a very few minutes. So, with professional help only minutes away, Dalhousie's practice is to:

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

If You Discover a Fire:

- T Sound the alarm by activating a pull station (located near any exit).
- T Leave the fire area helping others as necessary and closing doors behind you.
- T Do not use elevators. Use the stairs to reach the nearest exit.
- T Report the location and cause of the fire to a building fire warden, a security officer or the fire department.
- T Once outside, move at least 100 metres from the building.

To Fight a Small Fire:

- T Pull a fire alarm or have someone else activate it.
- T Ensure that you always have a clear escape route. Never let the flames get between you and the exit.
- T Assess the situation and choose the correct extinguisher, or smother the fire to deny it oxygen.
- T Evacuate immediately if you cannot completely extinguish the fire with a single extinguisher.

4.1.2 Choosing the Right Extinguisher

A. Ordinary Combustibles

Paper, wood, fabric and other ordinary combustible material fires can readily be extinguished using a water-filled extinguisher. At Dalhousie, all silver coloured extinguishers contain pressurized water for use on ordinary combustible fires.

B. Flammable Liquids and Energized Electrical Equipment

Carbon dioxide extinguishers are effective in extinguishing both flammable liquid and electrical fires. At Dalhousie, carbon dioxide extinguishers are red with a large diameter black nozzle. Using a CO_2 extinguisher releases very cold carbon dioxide which cools the extinguisher's black horn. Touching either the horn or the CO_2 "snow" can cause serious skin injury. To prevent harming others, **never discharge** a CO_2 extinguisher in the direction of any person.

Warning: Using water on burning solvents, oils, fats or other flammable liquids might spread the fire and ignite other, nearby materials. Similarly, water should not be used to fight fire in electrically energized equipment. As a water stream can conduct electricity, someone using water on a fire in energized electrical equipment could be electrocuted.

C. Multipurpose Extinguishers

Some Dalhousie laboratories are equipped with dry chemical extinguishers which may be used on fires involving ordinary combustibles, flammable liquids or energized electrical equipment. Dry chemical extinguishers are orange or red and resemble CO_2 extinguishers but they have a simple black hose instead of the large black plastic horn of a CO_2 extinguisher.

Discharging a dry chemical extinguisher releases lots of fine, fire retardant powder that effectively extinguishes many fires. However, the powder may present a significant clean up problem, particularly if it gets into sensitive electronic equipment.

4.1.3 Using a Portable Extinguisher

T Choose the correct extinguisher for the type of material that is burning.

T Ensure that you have a safe escape route.

P	PULL	the pin to release the handle.
A	AIM	the nozzle at the base of the fire.
S	SQUEEZE	the handles together.
S	SWEEP	the nozzle back and forth to extinguish the fire.

T Evacuate immediately if you cannot completely extinguish the fire with one extinguisher.

4.2 Dealing with Chemical Spills

Chemical spills are common laboratory accidents to which all staff and students should be prepared to respond. Planning ahead and equipping the laboratory with the required equipment usually ensures a quick, safe and effective response.

Spill response requires a 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 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.

Most departments have created spill kits which contain absorbants, protective equipment and a selection of small tools for use in responding to small chemicals spills. Information on the location of these spill kits and a list of the contents is available from your Departmental office.

If the Spill or Leak is Significant and There is Risk of Fire, Explosion or Toxic Levels of Airborne Contamination:

T Immediately evacuate the area, stopping the leak only if it is safe to do so.
T Close doors behind you.
T Warn others in the area to evacuate.
T Sound the building alarm.
T Report to the building fire warden, a Dalhousie security officer or the fire department alerting them to the nature of the emergency.

If You Feel Confident of Your Ability to Deal With the Spill and You are Sure that You and Others in the Building Are Not in Danger:

T Stop the source of the leak or spill.
T Extinguish sources of ignition.
T Provide ventilation.
T Wear protective equipment including lab coat, impervious gloves, safety glasses or goggles, face shields, aprons, and shoe covers or impervious boots as needed.
T Contain the spill.
T Neutralize or treat the spill to reduce the hazard.
T Collect liquid spills using clay or commercial absorbent products.
T Discharge neutralized liquid waste to a sewer if it does not represent an environmental hazard. Store other wastes for proper disposal.

For Spills of Acids:

T Neutralize the spill carefully using soda ash (sodium carbonate).

For Spills of Bases:

T Neutralize the spill carefully. Dilute with water and neutralize with dilute acid.

For Spills of Oxidizers:

T Remove any readily oxidizable materials from the area of the spill.
T Destroy the oxidizer by carefully adding sodium bisulfite solution.

For Spills of Potentially Infectious Material:

- T 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 for Chemical Exposures

As Dalhousie is well served by nearby hospitals and emergency response teams, our 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. But where the victim is not in immediate danger, the first aid provider should be careful not to unwittingly make injuries worse.

In responding to any accident, 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 an accident.

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.

To Control Bleeding:

- T Apply firm pressure to the wound using bandage, gauze or even a clean lab coat.
- T Do not cut off blood circulation beyond the wound.
- T Have someone alert security to call an ambulance.
- T Have the victim recline and elevate the wound if there is no sign of a broken bone and movement does not cause pain.
- T Except in the most severe cases a tourniquet will not be needed. Using one improperly could cause added harm.
- T Keep the victim warm and comfortable until medical assistance arrives.
- T Avoid contact with the victim's blood by wearing clean disposable gloves.

To Help When Someone Has Stopped Breathing:

T Have someone alert Security to call an ambulance.
T Tilt the victim's head back by gently pushing back on the forehead while lifting the chin to clear the victim's airway.
T Begin artificial respiration or CPR.
T Never give anything by mouth to someone who is unconscious.

If a person who has inhaled a dangerous material is able to move with only minor assistance, it is often helpful to move them to fresh air while awaiting the arrival of an ambulance.

Minor burns sometimes occur in laboratories. Immediately following the burn, there may not be any sign of skin damage. But within a very few minutes the skin will appear pink (or reddish), slight swelling and small blisters might be present.

To Treat Minor Burns:

T Immerse the burn in cool water until pain subsides.
T Cover the burn with a clean and sterile dressing.
T Do not apply butter or ointment as these may interfere with medical treatment
T Seek medical assistance for all serious burns.

A spill, a splash or an explosion that gets a chemical on someone's clothing, skin or in their eyes is another type of accident 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 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 ensure that all traces of the chemical are removed, flushing with running water should continue for at least a full 15 minutes.

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 poorly water soluble contaminants, flowing water is preferred to other solvents many of which might actually aid the absorption of the contaminant through the skin.

Phenol 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 accident. For even minor accidents with phenol, flush the affected area thoroughly with water only.

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. Staff and students in Dalhousie laboratories have ready access to eye wash stations for use in eye contamination accidents.

Laboratory staff and students should be familiarized with the location and operation of eye wash stations and emergency showers as part of an initial laboratory orientation.

To Use An Eye Wash Station:

- T Turn on the water.
- T Adjust the proportion of hot and cold water to provide a comfortable temperature if necessary.
- T Hold eye lids open, being careful not to introduce foreign material into the eyes.
- T Flush eye for a full 15 minutes.
- T Seek medical assistance.
- T Be prepared to provide the ambulance attendants with information on the chemical involved in the accident.

To Use An Emergency Shower:

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

Although accidental ingestion of chemicals is rare in laboratories, 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 Dalhousie laboratories.

In Cases of Chemical Ingestion:

T Have someone alert Security to call an ambulance.
T Have the victim rinse his or her mouth with large amount of water while avoiding swallowing the water.
T Keep the victim comfortable and calm while awaiting the ambulance.
T Be prepared to provide the ambulance attendants with information on the chemical involved in the accident.

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 contact the Dalhousie Safety Office for advice on antidotes.

5. PREVENTING HARM

5.1 Laboratory Practices

5.1.1 Laboratory Behaviour

Inappropriate behaviour can needlessly put people at risk.

To Avoid Harming Yourself or Others:

T Behave responsibly at all times.
T Warn co-workers about any unusual dangers associated with work you are doing.
T Follow the supervisor's instructions. Do not carry out unauthorized experiments.
T Use protective equipment as needed. Do not operate equipment improperly or without guards in place.
T Do not smoke in the laboratory.
T Do not store food or eat in the laboratory.
T Be careful with long hair or loose clothing around mechanical equipment.
T Keep work space tidy.
T Clean up spills promptly.

5.1.2 Working Alone

Some laboratory procedures require long hours and it is often not possible to work a "9 to 5" schedule. But working alone can be dangerous. Without someone around and able to help, an accident that would ordinarily be fairly minor could be very serious.

If You Must Work Alone:

T Do so only with your supervisor's permission.
T Let someone know you are working and have someone check on you periodically.
T Avoid particularly dangerous procedures.

5.1.3 Unattended Operations

Some laboratory procedures must run for extended periods and people may not always by present throughout the procedure. 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 damage. In serious cases, such a failure could endanger building occupants, custodians or service people, security officers or other emergency responders.

Failures that could cause damage or health or safety hazards include:

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

When planning an unattended operation, laboratory staff and students should carefully consider the possible implications of such failures. A protocol should 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 that indicates an unattended experiment in progress and the nature of the experiment and the hazard.

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

If particularly dangerous unattended experiments must be undertaken, fail safe controls or interlocks are required.

5.2 Laboratory Inspections

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

A formal laboratory inspection is normally carried out by the laboratory supervisor. Members of the departmental safety committee or departmental administrative staff may also take part. The purpose of an inspection is two-fold. The inspection surveys the physical facility as well as the laboratory's work practices to identify situations which could lead to an accident or an injury. Having identified a problem, the inspection also includes a follow-up component which corrects the problem.

By documenting the inspection and the follow-up, laboratory supervisors demonstrate their commitment to and support for laboratory safety.

Although there are many ways to carry out effective inspections, many people feel that using a good inspection check list reduces the chances of overlooking a possibly serious problem. To assist those who wish to use such an inspection form, a sample form is included. Additional copies are available from the Safety Office.

Although the form was designed primarily for use by the supervisor in formal inspections, laboratory staff and students may wish to use it in less formal but more frequent inspections of their laboratories.

Dalhousie
University

5.2.1

LABORATORY INSPECTION FORM

Building: Laboratory No.:

A.	SUPERVISION	Y	N	NA
1.	Has the supervisor assessed the likelihood that laboratory activities could cause harm and taken steps to minimize risks?			
2.	Are staff and students adequately supervised?			
3.	Does supervisor routinely monitor lab activities for compliance with safe practice?			
4.	Are food or beverages stored or consumed in the lab?			
5.	Are all accidents reported to the supervisor and the Dalhousie Safety Office? - Are appropriate steps taken to prevent re-occurrences?			
6.	Do staff and students use eye protection, lab coats, protective gloves and other required safety equipment?			
B.	INFORMATION AND TRAINING			
1.	Are staff/students trained in: - WHMIS - Transportation of Dangerous Goods - Nuclear Safety and Control Act - Safe lab practices - Techniques required for dangerous chemicals, organisms or equipment - Use of required protective equipment - Response to an injury, chemical or biohazardous material spill, fire or other emergency			
2.	Are Material Safety Data Sheets available at all times when people are working with chemicals?			
C.	CHEMICAL HANDLING			
1.	Are chemicals purchased in minimum practical quantities?			
2.	Is laboratory chemical inventory current?			
3.	Are chemicals moved safely - from receiving or stores to the laboratory? - to other locations?			
4.	Are containers (including those into which chemicals are decanted) properly labelled?			
5.	Are solvents and flammable and combustible liquids stored in - containers of 5 L or less? - volumes of less than - 16 L. per 10 sq. metres? - 16 L. per 10 sq. meters in a flammable liquid cabinet?			
6.	Are chemicals stored securely on shelves below shoulder height?			
7.	Are flammable chemicals requiring refrigeration stored in "lab safe" fridges?			

8.	Are compressed gas cylinders stored appropriately?			D. HAZARDOUS WASTE Y N NA
1.	Are procedures in place to minimize waste generation?			
2.	Are procedures in place to appropriately dispose of: - empty chemical containers - broken glass or other sharps - waste animal tissue - potentially infectious waste - radioactive waste - waste chemicals			
E.	EQUIPMENT			
1.	Is the lab equipped with appropriately operating fire extinguishers, fume hoods, biosafety cabinets, emergency showers, eyewash stations, protective equipment, first aid and spill response supplies and other needed equipment?			
2.	Does the laboratory provide an appropriate environment in terms of ventilation, lighting, means of egress, etc.?			
3.	Is particularly dangerous equipment (ultracentrifuges, X-ray generators, lasers, equipment operating at high voltage, etc.) tested or inspected regularly and properly maintained?			
4.	Is the lab entrance marked with information on emergency contacts and location and nature of lab hazards?			
5.	Are electrical wires, cable switches, etc. maintained in good condition?			
6.	Are extension cords used only for temporary situations?			
7.	Is the lab maintained in a tidy fashion?			
8.	Are aisles, doorways and exits kept clear of obstacles?			
9.	Is storage in fume hoods minimized?			
10.	Are tall storage units securely fastened in place?			
11.	Are drive belts and other rotating equipment properly guarded?			
12.	Is equipment operating at reduced or elevated pressure properly guarded?			
13.	Are lab staff and students protected from contact with very hot or very cold materials?			
F.	DOCUMENTATION			
1.	Is the lab's safety program properly documented?			
G.	FOLLOW UP - steps taken in response to inspection:			

Laboratory Supervisor:	Date:

5.3 Storage of Chemicals

The way in which chemicals are stored can have a major impact on laboratory safety.

Store Chemicals:

T In minimum practical quantities away from entrances.
T Protected from exposure to excessive heat or direct sunlight.
T Above floor level on shelves not higher than shoulder height.
T On shelves with a back which prevents chemicals from falling off the rear of the shelf.
T Separately from other incompatible chemicals.
T In safety coated bottles where appropriate.

5.3.1 Containers

Most laboratories store their chemicals in the container it came in. These containers are usually acceptable for storing chemicals in Dalhousie laboratories. However, because of their flammability and toxicity, solvents may be stored only in glass containers with capacities no greater than 5 L. Because of its extreme flammability and its ability to form explosive peroxides, diethyl ether may be stored only in glass containers with capacities of 1 L. or less. If the laboratory must store a larger volume of a solvent, it may only be stored in an approved safety can with a capacity no greater than 25 L.

It is important to carefully choose containers for stock solutions and reagent preparations. 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 Dalhousie 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. Laboratory staff and students working with such dangerous chemicals should always check the material safety data sheet before beginning work.

Store Chemicals:

T In the supplier's original container or in a container that provides adequate protection for the contents.

T In ground glass stoppered containers only when the stopper does not create a hazard.

T In containers bearing a label showing the chemical name and safe handling instructions.

5.3.2 Solvents

Solvents present serious fire and toxicity hazards. Although many factors influence the extent of the hazard, quantity is an important one. In recognition of the risk that solvents present, Dalhousie has adopted policies which limit solvent container sizes and volumes of solvents. Container sizes or volumes in excess of these limits must be stored in approved solvent storage rooms.

Storage of flammable liquids at a reduced temperature 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 as will the flammable vapour levels. 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 or has been appropriately modified to eliminate possible solvent vapour ignition. Refrigerators and freezers that are used to store flammable liquids must carry a notice indicting that flammable liquids are present.

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 meet the flammable liquid criteria and may only be stored in refrigerators or freezers designed for storing flammable liquids.

Store Solvents:

T 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.

T In quantities less than:

Total Solvent Volume (L. per sq. m.)	
Excluding quantities in safety cans or safety cabinets	Including quantities in safety cans or safety cabinets
0.8	2.5

T In refrigerators or freezers designed for storage of flammable liquids.

T In containers bearing labelled information giving the chemical name and safe handling instructions.

5.3.3 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

Professional judgement must be exercised in devising a storage system which properly separates incompatible chemicals in any particular laboratory but, in general, chemicals in each of these incompatible classes should be stored separately.

Inorganic Acids and Bases:

T Store acids and bases separately from other chemicals

T Provide a secondary means to contain a liquid spill.

T 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.

Solvents:

- T Store solvents separately from other chemicals, where possible in a flammable liquid cabinet.
- T Follow University policy regarding container size and laboratory volume limit.
- T Provide a secondary means of containment to control a liquid spill, if solvents are stored outside of a flammable liquid cabinet.
- T Protect solvents from exposure to flames or other sources of heat.
- T Store acetic acid as a flammable liquid rather than an acid.

Dangerously Reactive Chemicals:

- T Store reactive chemicals with regard for their reactive properties well separated from incompatible chemicals.

Oxidizers:

- T Store oxidizers separately from combustible materials and particularly from reducing agents.
- T Store perchloric acid as an oxidizer rather than as an acid.

5.4 Moving Chemicals

5.4.1 Between Dalhousie Buildings

Laboratory staff or students should not move chemicals between Dalhousie buildings without authorization of the Safety Office. Moving chemicals to or from Dalhousie property is subject to the Transportation of Dangerous Goods Act. Extensive labelling, placarding and documentation rules apply to such shipments. Federal government regulations require that only staff who have received TDG training may ship chemicals.

5.4.2 Within Dalhousie Buildings

Care is needed to prevent accidents while moving chemicals within a building and particularly through public areas of Dalhousie buildings. Exercise extreme care if you must use an elevator to move chemicals. Because elevator cars as so confined, a spill or leak of a chemical could result in a severe exposure. In addition, a liquid spill could contaminate the entire elevator shaft.

To Move Chemicals Safely in Dalhousie Buildings:

T Use a cart to move chemicals in containers larger than can be easily carried in one hand.
T Move liquids in a leak proof secondary container.
T Move inorganic acids and other corrosive liquids in "rubber buckets".
T Moving chemicals as received in the supplier's original shipping package is permitted.
T Be careful using elevators or stairs to move chemicals.

5.5 Laboratory Equipment

5.5.1 Fume Hood Safety

In many laboratories, the fume hood is the single most important safety feature. In essence, they are ventilated boxes with a movable transparent "window" through which one can see what is happening in the hood. In some 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 accidents.

Fume hoods are vented to the outside where dilution reduces exhausted contaminant concentrations to acceptable levels.

Fume hoods must work properly in order to protect humans from exposure to chemicals. To pull air through the fumehood and force it out of the building, the fan must be mounted in the exhaust duct. The fan should be placed outside the building and near the end of the exhaust stack. This arrangement places the hood and the duct at reduced pressure so, if there is a leak, air flows into, rather than out of, the exhaust duct.

A fume hood is supposed to efficiently trap contaminants that are released in the hood. To trap these contaminants, fume hoods 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 fumehood 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 fume hood fans operate at constant volume, the velocity of the air flowing into the hood would increase when the window is lowered. To prevent the air velocity from increasing and turbulence developing, most hoods have a compensating baffle over the window that keeps the face area constant.

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

Work practices can also dramatically affect hood performance. Fume hoods most effectively capture vapours created at least 6 inches into the fumehood. 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. They can all contribute to an escape of contaminants into the lab. When you need to put a bulky piece of equipment in a fumehood, you should raise it about 1 ½ inches using rubber stoppers or similar spacer. Raising the equipment in this way allows air to sweep the floor of the hood and minimizes the disruption in air flow.

Additional Reading:

1. **Laboratory Fume Hoods**, G. T. Saunders, John Wiley and Sons, 1993

5.5.2 Compressed Gas Safety

Hundreds 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. To prevent an accident, 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 Safety Office or your supplier of compressed gases.

To Avoid Compressed Gas Accidents:

T Never allow a cylinder to fall or bang against another cylinder.
T Move a cylinder by securing it to a cart designed for that purpose. Ensure that the regulator is removed and the valve cap is in place.
T Secure all cylinders to a bench or a wall with a strap or a chain before removing the cylinder cap.
T Store and use cylinders in a well ventilated area away from exposure to strong sunlight or other sources of heat
T Check Material Safety Data Sheet to ensure that incompatible compressed gases are not being stored together.
T Use only the regulator designed for use with the particular gas. If you have any doubts contact the supplier.
T Never use grease or oil on a regulator or valve.
T Never transfer gases between cylinders.
T Treat all cylinders as if they were full.

5.6 Protective Equipment

The use of protective equipment is a basic and mandatory precaution that people must always follow when working with chemicals in Dalhousie laboratories. Staff and students should not wear shorts or sandals, as they do not provide protection comparable to that afforded by trousers, skirts or normal shoes.

Protective equipment and clothing that must be worn whenever working with chemicals include:

T lab coats
T protective eye wear - chemical safety glasses with side shields, chemical goggles or, in extreme cases, face shields
T protective gloves

When skin contact with chemicals or potentially infectious materials is possible, laboratory staff should wear protective gloves. Disposable latex gloves are commonly used in Dalhousie 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 patient care and in clinical chemical laboratories. But they may not always be the appropriate choice. It has become clear recently that latex products can cause allergic reactions. People most at risk of developing serious allergies to latex seem to be those with frequent exposure to latex and who have personal or family histories of allergies.

In a chemical laboratory, latex gloves offer protection from light contact with many aqueous solutions. But they 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.

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 fabrics to a few common chemicals. Further information is available from the glove supplier.

Protection afforded by various glove fabrics:

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)	- -	resists ketones, aliphatic and aromatic solvents coating is water soluble
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 solely for protection. Instead, gloves should be treated as if it were skin. Before leaving the laboratory staff and students should remove lab coats, masks and protective gloves. These items may have become contaminated and wearing them in the public areas of the building could spread the contamination putting others at risk.

When Using Protective Gloves:

- T If gloves become contaminated, immediately wash the gloves and remove them if there is indication of deterioration.
- T Remove gloves carefully, avoiding unnecessary direct contact with contaminated areas of the glove.
- T Remove and discard the gloves and wash your hands thoroughly following work in protective gloves.
- T Do not wear protective gloves in public areas of your building.

Respirators and Masks

Dalhousie does not generally authorize staff or students to use chemical respirators. Respirators are designed to protect people from harmful levels of chemicals in the air.

Using a respirator in a dangerous atmosphere requires that:

- T the user make the correct choice of respirator,
- T the user know how to properly wear the respirator, and finally
- T 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, Dalhousie policy allows their use by only those who have been fully trained and who have been fit tested for the particular respirator.

A laboratory activity that might release a significant amount of a hazardous material must be carried out in a fume hood or controlled in some other fashion. A spill or leak that releases enough of a dangerous chemicals 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.

However, staff and students may use disposable masks, and in some situations they are required. When patient care is provided and there is concern about the airborne transmission of infection, disposable masks are required. Staff and students involved in such programs receive extensive instruction on infection control in which masks play an important role.

Disposable masks are also important in minimizing laboratory staff exposure to animal allergens. Dander, bedding and other material contaminated with animal excreta are potent respiratory allergens. The incidence of asthma and respiratory allergies are high among people who work with laboratory animals. Conscientious use of a properly selected disposable mask can prevent respiratory disease among people who work with lab animals.

5.7 Laboratory Waste

Research laboratories generate paper and other non-hazardous waste that are handled in the same fashion as similar waste generated elsewhere on campus. Your departmental office can provide you with information on refuse collection and recycling programs in your building. But laboratories also produce a variety of other wastes which cannot be discarded along with normal refuse.

At Dalhousie special practices are in place for the disposal of laboratory wastes including:

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

5.7.1 Chemicals and Empty Chemical Containers

As a general rule, chemicals may not be discarded with regular refuse or flushed down a drain. Such uncontrolled release of chemicals can cause health problems or environmental damage. Dalhousie collects and disposes of surplus and waste laboratory chemicals through the Safety Office.

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, the Safety Office operates a chemical exchange program, called ChemEx, which offers surplus chemicals to laboratories across campus and to neighbouring institutions.

Unfortunately, we cannot find alternative uses for all surplus chemicals. In addition to the unusable surplus chemicals, Dalhousie research and teaching laboratories annually produce thousands of kilograms of contaminated chemical waste. The Safety Office co-ordinates a waste chemical collection and disposal program to ensure the proper disposal of these wastes.

To reduce the likelihood of a laboratory fire, Dalhousie collects waste solvents regularly from buildings across campus. Laboratory staff are responsible for moving waste solvents to a designated location in each building from which the Safety Office collects and transports them to a central waste solvent store room. 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 disposal. More information on solvent disposal is available from your departmental office or from the Safety Office.

The University's laboratory disposal waste program collects other, non-solvent wastes early each summer. In preparation for the collection, a co-ordinator in your department contacts laboratory supervisors to obtain a waste inventory. Information included on the inventory which is needed to properly plan the disposal includes:

- 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,

T the approximate composition of mixtures or solutions,
T 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. In many cases, unknowns cannot be accepted for disposal.

The disposal program is critically dependent on laboratories maintaining good control of laboratory chemical inventories and ensuring that all chemicals are properly labelled.

Following collection, the work of preparing wastes for disposal begins. When possible, 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 for incineration at disposal facilities in central Canada. Waste oils are usually reprocessed at a local waste oil facility to produce re-refined products.

Other non-solvent wastes are also shipped to commercial chemical disposal facilities. Many of these chemical wastes must be chemically treated and stabilized to prevent migration and off-site contamination. These wastes are then buried in secure, monitored chemical landfill sites.

Some non-hazardous chemicals may be disposed of locally. Solids, such a simple sugars, salt and other non-toxic and environmentally benign chemicals, may safely be disposed of in regular garbage. Such chemicals should be securely packaged and labelled as "NON-HAZARDOUS WASTE". The label must also be dated and signed by the person authorizing the disposal. Non-hazardous waste chemicals may not be placed with regular laboratory trash. Instead they must be placed directly in the dumpster servicing the building.

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, call the Dalhousie Safety Office for advice.

Empty chemical containers must be cleaned of chemical residue and labels 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.

5.7.2 Waste Animal Tissue

All animal anatomical materials must be packaged to prevent leakage and stored refrigerated or frozen while awaiting pick up. Dalhousie's Environmental Services collects waste animal tissue regularly. The collection schedule is available from your departmental office.

Waste animal tissue from all Dalhousie laboratories is incinerated.

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 Safety Office.

5.7.3 Radioactive Materials

Disposal of radioactive materials is subject to special requirements enforced by the Canadian Nuclear Safety Commission. Much of the laboratory waste that contains radioisotopes is stored in secure locations until the level of radioactivity has decayed to levels that permit safe disposal by incineration or landfill. Additional information on disposal of radioactive waste is available through Dalhousie's Radiation Safety Program, your supervisor or the Dalhousie Radiation Safety Office.

5.7.4 Broken Glass and Other Sharps

Uncontaminated broken glass and other sharp materials must be packaged in sturdy, puncture-resistant containers. The container must be labelled as "SHARPS - HANDLE WITH CARE". The label should be signed and dated. These wastes may be deposited directly in the dumpster which serves your building.

Sharps that are contaminated with chemicals, or radioactivity should be collected and packaged in the same fashion as uncontaminated sharps. In addition to the labels described above, the label must indicate the nature of the contamination. For information on the appropriate disposal route for contaminated sharps, consult your supervisor or call the Safety Office.

5.7.5 Potentially Infectious Waste

All waste that might contain a pathogen must be handled in a way that minimizes the risk of infection following the supervisors directions and using protective equipment as necessary. Autoclaving is one 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. Waste material destined for autoclaving is usually placed in special orange bags which carry the biohazard symbol.

It is normally safe to dispose of wastes that have been autoclaved along with regular trash. Following treatment in an autoclave, waste should be placed in a second bag or other container or the bioinfectious symbol defaced to avoid giving waste handlers the impression that the contents present a biohazard. Detailed procedures for collecting the waste, using the autoclave and for disposing of already autoclaved waste are available from your supervisor.

Note 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.

Other potentially infectious wastes are segregated from other wastes, collected in special yellow bags and transported for incineration at the pathological waste incinerator at the Victoria General Hospital. Waste that might be contaminated with blood and saliva from patient care in the Dalhousie Dental Clinic is handled in this fashion. Staff and students providing patient care in Dentistry receive detailed training in this and other aspects of infection control.

Sharps such as syringes and needles contaminated with blood or other infectious materials must be placed in special puncture-resistant containers designed to prevent needle stick injuries. When half full, these containers should be collected and sent for disposal by incineration. Again, ask the Safety Office, your supervisor or your departmental office for details.

APPENDIX A. WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM

The Workplace Hazardous Materials Information System (WHMIS), as the name implies, is a system that is designed to provide information to employers and employees so they can safely organize work with dangerous chemicals. WHMIS was developed by representatives of the federal and provincial governments, unions and employer organizations. The program was implemented in the late 1980's by a series of acts and regulations passed in each provincial legislature and in Ottawa. In Nova Scotia, both the Occupational Health and Safety Act and two WHMIS regulations provide the legal basis for the system. Although there are different pieces of legislation in each Canadian jurisdiction, each is based upon a single model so WHMIS requirements are consistent across the country. WHMIS places obligations on suppliers of hazardous products as well as employers who use these products.

A.1 Application

WHMIS requirements generally apply to chemicals sold for use in the workplace. But a few types of chemicals that are regulated under other pieces of federal legislation are exempt from WHMIS requirements. Included among these exemptions are:

T consumer products,
T cosmetics, food and drugs (covered by the Food and Drug Act),
T explosives (covered by the Explosives Act),
T hazardous waste,
T manufactured articles,
T pesticides (covered by the Pest Control Products Act),
T products in transportation (covered by the Transportation of Dangerous Goods Act),
T radioactive materials (covered by the Nuclear Safety and Control Act),
T tobacco and tobacco products,
T wood and wood products.

Although these materials are not formally covered by WHMIS, the Nova Scotia Occupational Health and Safety Act still applies when workers use these chemicals. And the employer is still required to provide employees with the health and safety information they need to work safely with the product. When dealing with an exempted chemical, the simplest way for the employer to meet these information requirements is to act as if WHMIS applies. Pressure from employers using these exempted products has, in most cases, led manufacturers of exempted products to comply voluntarily with WHMIS requirements.

WHMIS also contains a special provision for chemicals used in a laboratory. To qualify for the exemption, the chemical must:

T originate from a laboratory supply house,
T be intended for use in a laboratory, and
T be packaged in a container of less than 10 kg.

Products which meet all these terms are subject to a more limited range of information requirements.

A.2 Controlled Products

WHMIS is a criteria driven system. The suppliers of chemicals must compare their products against a detailed set of technical criteria. If it meets any of the criteria, a product is subject to WHMIS and is termed a controlled product. Products which do not meet any of the criteria are exempt. Such exempted chemicals present very low health or safety hazards.

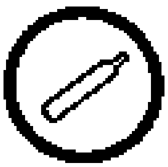
A.3 WHMIS Criteria

WHMIS divides hazardous materials into six classes, several of which are further divided into divisions and even subdivisions. Each WHMIS class (and in some cases divisions within the class) is assigned a symbol. The symbol is always contained within a circle which sets WHMIS symbols apart from the symbols used in the Transportation of Dangerous Goods, and on labels of pesticides and hazardous consumer products.

WHMIS symbols are intended to help people quickly identify the nature of the hazard. WHMIS symbols are a required component of supplier labels.

The criteria, against which the supplier compares the properties of an unclassified material, are quite complex and, in some cases, quite technical. What follows is a very brief and quite simplified summary of the criteria for each of the six WHMIS classes.

Class A Compressed gases (symbol compressed gas bottle)

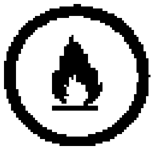


Chemicals in a container under pressure which has:

T a critical temperature less than 50 C. or
T an absolute vapour pressure over 294 kpa or
T an absolute pressure -
    over 275 kpa at 21.1 C. or
    over 717 kpa at 54.5 C.
T or as a liquids has an absolute vapour pressure over 275 kpa at 37.8 C.

Class B Flammable and Combustible Materials (symbol flame)

Division 1 Flammable gases:



T gases which at atmospheric pressure form flammable mixtures with air at concentrations less than 13% (for example butane LEL 1.9%)
T gases which at atmospheric pressure form flammable mixtures with air over a concentration range greater than 12% (for example hydrogen explosive range is 4% to 70% or a range of 66%)

Division 2 Flammable liquids:

T liquids with flash points below 37.8 C. (for example benzene fp-11 C.)

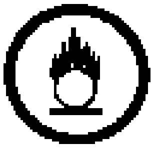
Division 3 Combustible liquids:

T liquids with flash points between 37.8 C. and 93.3 C.

Division 4 Flammable solids:

T solids which cause fires through frictional heating (for example phosphorus)
T solids which ignite easily and which burn vigorously and persistently (for example manganese)
T solids which easily ignitable and burn with a self-sustaining flame

Class C **Oxidizers (symbol flame over an O)**



T materials which contribute to the combustion of other materials by yielding oxygen or other oxidizers (for example perchlorates and permanganates)

T organic peroxides (for example benzoyl peroxide)

Class D **Toxic and Poisonous Materials**

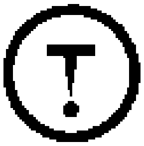
Division 1 Materials Causing Immediate and Serious Toxic Effects (symbol skull and crossed bones):

T chemicals which display acute lethality by oral, dermal or inhalation exposure

subdivision A - very toxic
subdivision B - toxic

Division 2 Materials Causing Other Toxic Effects (symbol T over a period):

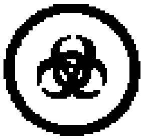
T materials which irritate the skin or eyes



T materials which cause toxic effects following prolonged exposure including such toxic effects as chronic toxicity, mutagenicity, sensitization, carcinogenicity, reproductive toxicity, teratogenicity and embryotoxicity

Division 3 Biohazardous Infectious Material (symbol three interlocking broken circles):

T organisms which cause disease and the toxins produced by such organisms (for example some viral, bacterial, rickettsial, fungal, protozoal, helminthic organisms)

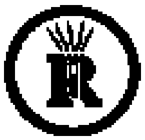


Class E **Corrosive Materials (symbol acid dripping on skin and metal bar):**

T materials which corrode metals such as steel or aluminum

T materials which corrode skin

Class F **Dangerously Reactive Materials (symbol exploding R):**



T materials which undergo vigorous polymerization, decomposition or condensation (for example 1,3-butadiene)

T materials which are self-reactive when subject to heat, shock or pressure (for example metal acetylides or azides and picric acid)

T materials which react vigorously with water to release a toxic gas

A.4 Supplier Duties

Having determined that a product meet one or more WHMIS criteria, the supplier must fully classify the product. Using the results of the classification, the supplier must:

T label the product according to the WHMIS protocol and

T provide purchasers with a Material Safety Data Sheet (MSDS)

MSDS are documents that convey a specified set of data on the physical, chemical and toxicological properties of the product and provide advice on product storage and use.

A.5 Employer Duties

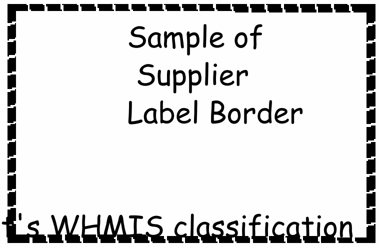
The employer is obligated to train employees so they understand WHMIS and are able to use the information that the system provides. Beyond simply training in WHMIS, the employer must also train employees in how to work safely with any chemical encountered in the course of work.

The employer must ensure that all controlled products are properly labelled. Acceptable labels are the supplier's label, for chemicals as received, or a "workplace label" that is required for a controlled products created in the workplace or for a container of chemical decanted from a supplier container.

The employers must also ensure that employees have access to current MSDS at all times when they are working with controlled products. Supplier MSDS's are valid for three years form the date of issue.

A.6 Supplier Label

Figure A.1 shows the elements than must be present of a supplier label. These elements include:



T Supplier identifier
T Product identifier
T Risk phrases
T Precautionary measures
T First aid measures
T Pictogram illustrating the product's WHMIS classification
T Statement indicating the availability of a MSDS
T Distinctive WHMIS label border
T Presentation in both English and French

A.7 Workplace Label

Good safety practice requires the labelling of all products. In most cases, the need for labels on chemical containers is met by the supplier label. But if the supplier label is damaged, if the hazardous material is produced within the workplace, or the chemical is decanted from a larger container to smaller one, WHMIS requires that the employer label the container.

The requirements for a workplace label are much less precisely defined than they are for the supplier label. The essential measure of an acceptable workplace label is that it quickly and accurately conveys the necessary safety information. Placards, labels or even paint colours can be used in some situations to effectively "label" pipe systems, reaction vessels and the like.

But in most cases, an actual label needs to be applied to the container. The WHMIS requirements for these labels include:

T Product identifier
T Safe handling information
T Reference to the availability of a MSDS

A.8 Material Safety Data Sheet

WHMIS allows the supplier some leeway in how the data sheet presents the health and safety information. But WHMIS does specify the sections which must be present on the MSDS.

The required sections include:

T hazardous ingredients including chemical name, registry number and acute toxicity data
T preparation information including the name and phone number of person preparing the data sheet and the date of preparation
T product information including the supplier's name, address and phone number, product name and use
T physical data including state, odour, appearance, specific gravity, vapour pressure and density, evaporation rate, boiling point, freezing point, pH and coefficient of water/oil distribution
T fire and explosion hazard including condition of flammability, means of extinction, flash point, upper and lower flammable limits, auto-ignition temperature and explosion data
T reactivity data including conditions under which product is unstable, incompatible chemicals and hazardous decomposition products
T toxicological properties including route of entry, effect of acute or chronic exposure, exposure limits, toxic effects and synergistic products
T preventive measures including needed personal protective equipment, engineering controls, spill and waste disposal procedures, handling and storage precautions and shipping information
T first aid measures

B. WHMIS in Dalhousie Research Laboratories

Technically WHMIS only applies to people who deal with chemicals in the course of employment. Therefore, University staff, grant paid technicians and faculty are subject to the WHMIS regulation while students would not be covered. However, in practice, Dalhousie has not differentiated between students and employees in safety matters. Dalhousie requires that all laboratory activities be carried out in accord with WHMIS requirements.

Dalhousie's laboratory WHMIS program includes:

T training
T labelling of chemical containers
T provision of MSDS

B.1 WHMIS Training

Staff and students in research laboratories need a combination of training and individual instruction to be able to carry out their laboratory work safety.

Although, depending upon the nature of the research, they might also need training in other areas of laboratory safety, all staff and students who work with chemicals in Dalhousie laboratories must be familiar with WHMIS and its requirements. To help laboratory supervisors meet this training requirement, the Safety Office offers a series of WHMIS training courses each year. Training schedules are available from Safety Office.

Those who have received training elsewhere may not need to attend a training course. But to demonstrate their familiarly with WHMIS, these people must complete a brief quiz which is again available from the Safety Office.

B.2 Chemical Labelling

Proper labelling is fundamental to laboratory safety. Unlabelled chemicals could expose the researcher, other laboratory staff and students, service personnel, and emergency responders to serious and unnecessary risks. Chemical labels that are acceptable in Dalhousie laboratories are:

T the original supplier label or
T a laboratory label which provides:
    - chemical name (not abbreviated)
    - the hazards, and
    - the required precautions

Where the container is too small to accommodate a complete laboratory label, a system must be developed that provides ready access to this information.

B.3 MSDS

Staff and students in Dalhousie research laboratories must have ready access to MSDSs or equivalent information for every hazardous chemical in the laboratory. A laboratory can comply by having paper copies of MSDS on hand, by having computer access to MSDS or by a combination of the two. The MSDS or the computer must be within reasonable proximity of the laboratory, so that staff and students can gather information in both routine and emergency situations. The MSDS must also be available at all times when laboratory staff are working with chemicals. So for example, a binder of MSDS that is only available from a departmental library between 9:00 am and 5:00 pm, would not comply if chemicals are used outside these hours.

B.3.1 Electronic MSDS Systems

Both suppliers and users of chemicals are beginning to understand the opportunity that the growth of the computer presents in helping to manage chemical information. In response to these developments, a growing number of suppliers of laboratory chemicals have begun to offer electronic access to MSDS's. These systems operate around the clock. So, directly from the laboratory computer, researchers are increasingly able to retrieve and, if necessary, print a MSDS quickly and easily at any hour of the day or night. The researcher can now often locate a MSDS more quickly by searching a computer system than by manually searching through a binder of data sheets. And for laboratories with large chemical inventories, electronic systems can save countless hours that would otherwise have to be spent in gathering, filing and updating MSDS's.

Through its internal communications network, Dalhousie has for many years offered researchers access to a MSDS collection in a system maintained by the Killam Library. The Internet has now made even this local system redundant. Virtually every supplier of laboratory chemicals now offers web-based access to its MSDS collection.

Given that the Internet already gives better coverage than we can offer through a local system, the Safety Office has opted to discontinue the Library system. Instead, the Safety Office offers the researchers with quick links to some of the best MSDS collections on the Internet.

To Find a MSDS:

Go the Safety Office web site: **http://www.dal.ca/safety**

Click on: **Chemical & Laboratory Safety**

Scroll down to: **INTERNET MSDS COLLECTIONS**

Choose the appropriate supplier.