a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

LABORATORY CHEMICAL SAFETY

Okanagan Campus

REFERENCE MANUAL
2011

Vancouver Campus Version Author, Noga Levit

Modified for the Okanagan Campus: Dave Cavezza

Department of Health, Safety & Environment
www.ubc.ca/okanagan/hse

Emergency Contact Information

UBC Campus - Okanagan

Fire, Police, Ambulance **911**
Emergency / First Aid / Security ..... **250 80(7-8111)**
Health, Safety and Environment ..... **250 80(7-8111)**
Hazardous Materials Response **911**
Poison Control **1-800-567-8911**

Non-Emergency Numbers

Parking and Campus Security (Non-Emergency) ..... **250 80(7-9236)**
UBC Health, Safety and Environment, Okanagan ..... **250 80(7-8624)**
UBC Health, Safety and Environment, Vancouver **604.822.2029**
Facilities Management ..... **250 80(7-9272)**
Health & Wellness (students) ..... **250 80(7-9270)**
R.C.M.P. (Non-Emergency) **250.762.3300**
Fire Department (Non-Emergency) **250.469.8801**
Kelowna General Hospital Emergency Department **250.862.4485**
Employee and Family Assistance program (EFAP) **1-800-663-1142**

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FOREWORD

The safe use, storage, handling, waste and emergency management of chemicals in the laboratory environment are the subject of this reference manual. Chemicals are used, to one degree or another, in most university laboratories. The advent of WHMIS (Workplace Hazardous Materials Information System) in 1988 gave employees the legal right-to-know about the hazards of the materials used in the workplace and to receive the training necessary to use these materials safely. Details on specific types of chemical hazards as well as commonly used equipment and procedures are outlined on the following pages. The information in this manual is meant to meet the needs of those who work, study and teach in laboratories at the University of British Columbia.

This manual is a modification of Chemical Lab Safety Manual produced by Risk Management Services at the UBC Vancouver campus (Author: Noga Levit). While the majority of the information is identical to the Vancouver manual, there are noticeable differences in the areas of Emergency contact information, waste management and spill response. Please ensure that you are using the manual specific to your campus.

DISCLAIMER

The information included in this manual has come from a variety of reliable sources. This manual is intended for the use of University of British Columbia personnel as an appropriate starting point for the development of safe and best management practices in UBC laboratories where hazardous chemicals are used. The material contained within is correct to the best of knowledge of the University of British Columbia's Departments of Risk Management Services and Health, Safety and Environment. However, there is no guarantee or warranty that it is without errors or omissions. Please contact Health, Safety & Environment with any concerns that you have regarding this manual.

I. Introduction

1.1 Department of Health, Safety & Environment (HSE)

UBC's Department of Health, Safety & Environment (HSE) is responsible for:

- developing and maintaining effective accident prevention programs;
- providing the University community with required training;
- assisting the University in complying with health, safety and environmental regulations; and
- enhancing departmental services.

1.2 Duties and Responsibilities

The Work Safe BC Occupational Health and Safety Regulation (Section 3.4[a]) and the UBC Safety Policy clearly define the roles and responsibilities of the employer, employee and students at UBC.

The university, acting through administrative heads of unit, is responsible for providing a safe, healthy and secure working environment for all those involved in the university's activities.

Supervisors are responsible for the following: identifying all hazards; ensuring that there are safe work procedures and appropriate emergency procedures; ensuring that all workers and students know and follow those procedures; and correcting unsafe conditions and practices. A supervisor is anyone who has been delegated responsibility for others working or studying at UBC.

All students and members of faculty and staff are responsible for learning and following safe work procedures and emergency procedures as well as reporting all unsafe conditions and incidents or accidents.

1.3 Incident/Accident Reporting

UBC's Faculty & Staff Incident/Accident Report form must be completed for every incident or accident, even if no injuries were sustained. If the injured person is a student or visitor to campus, the UBC Student & Visitor Incident/Accident Report form must be completed. Any event that involves injury to a person or damage to property, or has the potential to do so, must be reported to HSE within 24 hours of occurrence. There is also a WorkSafeBC form that injured employees have to complete.

Accident/Incident reporting forms can be viewed at www.ubc.ca/okanagan/hse/safety/accidents

Incidents involving serious injury (or the potential for serious injury), or release of hazardous materials, must also be reported immediately by dialing the University's emergency number: 7-8111 (internal) or 250-807-8111 (external).

1.4 Chemical Safety Program

The Chemical Safety Program promotes the safe handling, storage and disposal of chemicals that is compliant with the regulations and recognized best practices. Through this program employees receive chemical safety training, advice and guidance.

The Chemical Safety Course is provided to the Okanagan Campus in a two part series. The first portion is self directed through WebCT. After successful completion of the on-line course, participants register to attend a practical session. After passing a final exam, participants will Visit www.ubc.ca/okanagan/hse/register/whmissafety to register.

A glossary of terms used in describing chemical hazards and regulations can be found at the end of this manual.

1.5 Chemical Storage Depot (CSD)

The purpose of this facility is to safely manage hazardous waste generated at the University of British Columbia in accordance with provincial, local and federal regulations.

Chemical waste is collected regularly and taken to the CSD by HSE staff. It is sorted, treated and packaged according to type before being shipped for disposal. Hazardous Materials requiring disposal are submitted to HSE through the Hazardous Material Information System (HWIS) which is accessed through the Environment section of the HSE website (www.ubc.ca/okanagan/hse/environment.html). Information regarding chemical waste disposal can be obtained through the Laboratory Pollution Prevention and Hazardous Waste Disposal Manual.

II. General Laboratory Safety Rules

2.1 Work Habits

- Do not store food or beverages in the laboratory environment.
- Do not pipette by mouth.
- Do not dispose of chemicals down the drain
- Wash hands before and after work in a laboratory, and after spill clean-ups.
- Restrain loose clothing (e.g. sleeves, full cut blouses, neckties etc.), long hair and dangling jewelry.
- Protection should be provided for the lab worker and for nearby co-workers.
- Always inform co-workers of plans to carry out hazardous work *before* starting.
- Review all procedures before commencing any work
- Always wash your hands before leaving lab.
- Never work alone

2.2 Safety Wear

- Lab coats must be worn at all times in the laboratory.
- Closed toed shoes and long pants must be worn in the lab.
- Wear gloves that will resist penetration by the chemical being handled.
- Inspect gloves regularly for damage (pinholes, tears, or rips).
- Always wear ANSI (or equivalent standard) approved eye or face protection when working with chemicals in the laboratory. Match your eye / face protection to the hazards in the lab.
- Contact lenses are strongly discouraged
- Use respiratory protection (dust mask or respirator) when appropriate. Ensure that you are fit tested yearly to wear a respirator.

2.3 Facilities & Equipment

All operators of laboratory equipment must be adequately instructed and trained in the safe use of laboratory equipment and the precautions to be taken when the equipment is used.

- All moving belts and pulleys must have safety guards.
- Keep up-to-date emergency phone numbers posted next to the phone.
- Have appropriate equipment and materials available for spill control; replace when necessary.
- Always keep up with housekeeping in the laboratory (floor must be dry at all times).
- Floors, walkways, hallways, and stairways must be kept clear at all times to eliminate slipping and tripping hazards.
- Access routes to emergency equipment (emergency showers and eyewash facilities, fire extinguishers, first aid kits) must be kept clear of obstruction. Keep area around emergency equipment clear and clutter-free.
- All laboratory equipment must accompany safe operating procedures

2.4 Purchasing, Use and Disposal

- Label all chemicals accurately with date of receipt, or preparation, and initialed by the person responsible. Add pertinent precautionary information for handling.
- Never open a reagent container until the label has been read and completely understood.
- Unlabeled bottles must be identified to the extent that they can then be classified as hazardous or non-hazardous wastes.
- Incompatible and hazardous wastes are properly segregated in clearly marked containers affixed with workplace labels.
- Disposal of solvents must meet all municipal, provincial, and federal regulations.
- Only order what you need.

2.5 Substitutions

- Where possible, reduce risks by using diluted substances instead of using concentrates.
- Use micro/semi-micro techniques instead of macro-techniques.
- Use films, videotapes, and other methods rather than experiments involving hazardous substances where possible.
- Evaluate all substitutions before changing procedures.
- Always substitute a less toxic material when possible.

III. Chemical Hazards and the Workplace Hazardous Materials Information System (WHMIS)

3.1 Introduction

Information regarding safety and health hazards of materials used in the work place can be obtained through the Workplace Hazardous Materials Information System (WHMIS). This system requires suppliers to provide safety information with their products and requires the University to educate and train everyone potentially exposed to hazardous materials.

This chapter will provide basic information about the key elements of WHMIS:

- **Labeling –** alerts workers to the identity and dangers of products and to the basic safety precautions;
- **Material Safety Data Sheets** (MSDS) – technical bulletins which provide detailed hazard and precautionary information; and
- **Worker education and training**.

3.2 Background

The purpose of WHMIS is to help reduce the likelihood of disease or injury in the workplace. It was developed through the collective efforts of labor, industry and federal, provincial and territorial regulatory agencies. WorkSafeBC has been active in formulating the system and producing the written materials for its implementation.

Legislation to implement WHMIS has been enacted on both the federal and provincial/territorial levels. Federal requirements deal with the importation and sale of controlled products; provincial legislation covers the storage, handling and use of controlled products in the workplace.

Provincial legislation, through amendments to occupational safety and health regulations, declares the responsibility of the employer to provide:

- Workplace labeling and identification;
- A material safety data sheet where the employer uses a controlled product;
- Worker education on controlled products.

What is a controlled product?

A controlled product is a material that exceeds hazard criteria for inclusion in the WHMIS hazard classes and divisions. The six classes and eight symbols for WHMIS controlled products are presented in a table in Section 4: Chemical Hazards and Handling.

Some products are exempted from WHMIS since they are regulated by separate legislation:

- Consumer products
- Cosmetics and drugs
- Explosives
- Pesticides
- Radioactive materials
- Trade secrets

A more detailed resource for WHMIS can be found in WorkSafeBC's publication "WHMIS at Work"

Recently a new information system has been established: *GHS* stands for "Globally Harmonized System of Classification and Labeling of Chemicals". This system's goal is to have the same set of rules for classifying hazards, and the same format and content for labels and safety data sheets (SDS) will be adopted and used around the world. An international team of hazard communication experts developed GHS. Some suppliers will be using this system while Canada is in transition from WHMIS. An explanation of the differences between the two can be found at the CCOHS website.

3.3 Labels

All controlled products must be labeled according to WHMIS regulations.

Labels must be replaced if they become illegible or damaged. Illegible labels can create first aid, handling, and disposal problems.

Two types of labels are required under WHMIS:

- Supplier labels, produced by the supplier of the controlled product
- Workplace labels, produced by the employer for use in the workplace

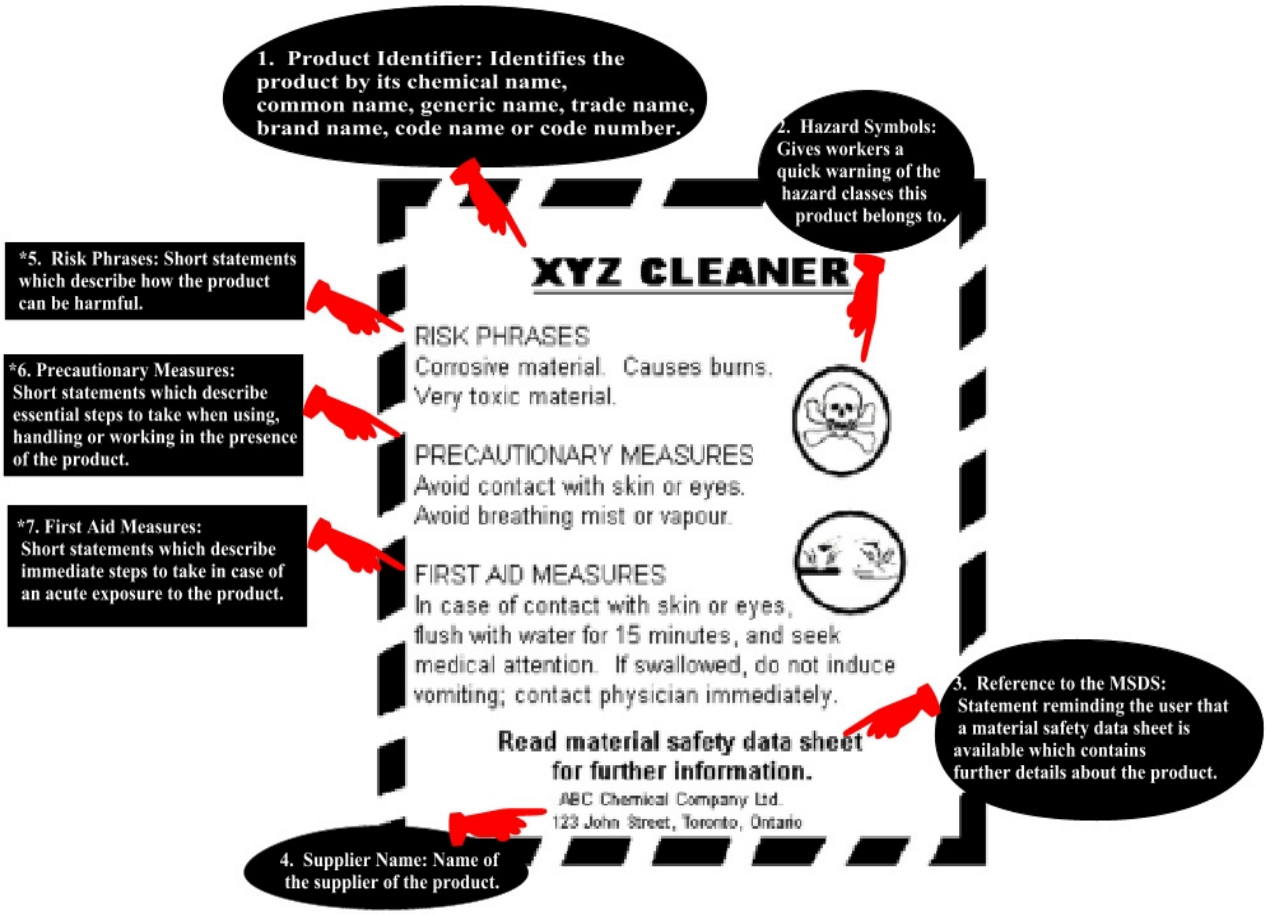
Supplier labels

Supplier labels carry brief statements to inform workers about the risk posed by the chemical, precautionary measures they should take, and first aid measures in the event of injury. A supplier label is not meant to provide complete health and safety information about a product.

Seven items of information must be included within the distinctive hatched border:

1. Product Identifier: Identifies the product by its chemical name, common name, generic name, trade name, brand name, code name or code number.
2. Hazard Symbols: One or more of the eight WHMIS symbols indicating the hazard classes of the product.
3. Reference to MSDS: Indicates that an MSDS is available.
4. Supplier Information: Name of the supplier, manufacturer or distributor, preferably with the address and telephone number.
5. Risk Phrases: Short statements, which describe how the product can be harmful.
6. Precautionary Statements: Statements that describe essential precautions to take when using, storing, and disposing of the product.
7. First Aid Measures: Statements that describe immediate first aid measures required.

Below is an example of an acceptable supplier label:



There are four different types of supplier labels. They apply to:

- **Laboratory chemicals** – products from a laboratory supply house, packaged in quantities of less than 10 kg and intended for use in a laboratory
- **Laboratory samples** – samples of a controlled product that are intended solely to be tested in a laboratory (such as for analytical or research and development purposes), packaged in quantities of less than 10 kg
- **Workplace chemicals** (> 100 mL) – products other than laboratory chemicals or samples and packaged in containers of more than 100 mL
- **Workplace chemicals** (< 100 mL) – products other than laboratory chemicals or samples and packaged in containers of less than 100 mL

The table below summarizes the information required on different supplier labels.

Information Required on Label	Laboratory Chemical	Laboratory Sample	Workplace Chemical > 100 mL	Workplace Chemical < 100mL
Product Name	•	•*	•	•
Hazard Symbols (classification)			•	•
Risk Phrases	•		•	
Precautionary Statements	•		•	
First Aid Measures	•		•	
Supplier Identification		•	•	•
Reference to Availability of MSDS	•		•	•
English in a Hatched Border	•	•	•	•

*Requires emergency telephone number and chemical identity
Taken from [Laboratory Health and Safety Handbook] – WorkSafe BC

Chemical identification and workplace labels

- If a chemical is transferred from the original container and is for use exclusively within the laboratory, or if the chemical is a controlled product undergoing analysis (e.g. a lab sample), the employer must ensure that the contents are clearly identified on the container.
- In cases where chemicals will not be used exclusively in the laboratory, employers must ensure that workplace labels are prepared and applied as required by WorkSafeBC Regulations.
- If chemicals are transferred from the original container into another container or mixed with other chemicals to produce a different chemical, a workplace label must be generated and attached to the new container. Workplace labels must be placed on each container of hazardous waste handled or disposed of by the laboratory.

Workplace labels must include:
- The product identity
- Safe handling information, including PPE required
- Reference to material safety data sheet

Labels must be replaced if they become illegible.

Other Identification requirements

Refrigerators and freezers need content identification and whether or not they are explosion-proof.

Chemical storage cabinets are required to have content identification signage with one of more of the WHMIS Hazardous Class symbols.

Cleaning baths and pipes require chemical name and/or WHMIS Hazardous Class identification.

3.4 Material Safety Data Sheets

The data sheet is the second element of the WHMIS information system and supplements the safety information that labels provide. This data sheet, also known as a material safety data sheet (MSDS), is a technical bulletin which provides detailed hazard, precautionary and emergency information on a product. WHMIS provides minimum content requirements for data sheets:

- Product information
- Hazardous ingredients
- Physical data
- Fire and explosion hazard
- Reactivity data
- Toxicological properties (health effects)
- Preventive measures
- First aid measures

Preparation information with date of preparation, name and phone number of persons or corporate departments to be contacted for additional information

Specific MSDS's can be found at the CCOHS website.

Suppliers
Suppliers must develop or obtain an MSDS for each controlled product they sell or import. Information must be current and prepared not more than three years before sale or importation. A copy of the MSDS must be sent to the purchaser at the time of first purchase. Purchasers may request data sheets in either or both of the official languages. An MSDS is a technical bulletin, which provides detailed hazard, precautionary and emergency information on a product.

Employers
Employers must ensure that MSDS are received for all controlled products supplied to the workplace. The employer must contact the supplier for an updated sheet when the data sheet at the workplace is more than three years old.

If the employer produces a controlled product for use at the workplace, the employer must develop an MSDS to accompany workplace labeling for it. Such data may be in the language of choice at the workplace.

Copies of supplier and employer MSDS must be accessible to employees, close to their work areas and available during each work shift. MSDS may be hard copies or available on a computer if the employer takes all reasonable steps to keep the system in active working order (e.g. if the power goes out, the system is still accessible). Workers must know how to access MSDS, and must be educated in the content required on the data sheet and the applicable information in it

3.5 Worker Education and Training

WHMIS education is required for anyone who:

- Stores, handles, uses or disposes of a controlled product or supervises workers performing those duties;
- Serve as emergency personnel;
- Performs maintenance or cleaning in the vicinity and may be exposed to spills or other accidental releases of controlled products; or
- Works near the controlled product such that their health and safety could be at risk during normal storage, handling, use or disposal, during maintenance operations or in emergencies.

The University establishes education and training programs for workers including:

- How WHMIS is implemented;
- The hazards of controlled products;
- Procedures for the safe storage, handling, use and disposal of a controlled product; and
- Emergency procedures addressing spill or release of controlled products.

Training must ensure that workers are able to apply hazard information to protect their own health and safety.

Training and education programs must be reviewed at least once a year, if conditions at the workplace change or new hazard information on the product changes the known risk to workers.

IV. Chemicals Hazards and Handling

4.1 Introduction

Chemical hazards are defined under WHMIS according to one of six hazard categories: (A) compressed gases, (B) flammable and combustible materials, (C) oxidizing materials, (D) toxic materials, (E) corrosive materials, and (F) dangerously reactive materials. In this chapter, characteristics and examples of these six hazard classes will be discussed. Additional sources of information can be found in the "References" and "Appendices" sections of this manual.

WHMIS regulations require employers to educate workers in the safe handling, use and storage of these products in the workplace.

Hazard Symbol & Definition	Associated Hazards	Handling Information
Class A - Compressed Gas 	• an explosion hazard because the gas is being held in a cylinder under pressure • container can explode if heated in a fire • container may explode if dropped	• do not drop cylinder • keep cylinder away from potential sources of ignition • store containers in a designated area • secure in an upright position
Class B - Combustible and Flammable Materials 	• the material burns or represents a fire hazard • may burn at relatively low temperatures; flammables will ignite at lower temperatures than combustibles • may burst into flame spontaneously in air, or release flammable gas on contact with water • may cause fire when exposed to heat, sparks, flames or friction	• keep away from heat sources and oxidizing materials • never smoke in vicinity • store in cool, fire-proof area, as designated by supervisor
Class C – Oxidizing Materials 	• poses fire/explosion risk in presence of Class B materials • may cause fire, react violently or cause explosion in the presence of combustible materials such as wood and solvents • may react violently with reducing agents • may burn skin and eyes upon contact	• keep away from Class B materials • store in designated area • keep away from ignition sources • never smoke in vicinity • wear eye, face, and hand protection, and protective clothing

Class D - Division 1 **Poisonous and Infectious Materials Causing Immediate and Serious Toxic Effects**	• potentially fatal substances • may be fatal or cause permanent damage if inhaled, swallowed or absorbed into body • may burn eyes or skin upon contact	• handle with extreme caution • avoid contact with skin or eyes; wear appropriate personal protective equipment and clothing • avoid inhaling; work in well-ventilated area and/or wear respiratory protection • wash and shower thoroughly after each use • store in designated areas only
Class D - Division 2 **Causing Other Toxic Effects**	• not immediately dangerous to health • may cause death or permanent damage as a result of repeated exposures over time • may be skin or eye irritant or sensitizer • may cause cancer • may cause reproductive or teratogenic effects	• avoid eye, skin contact by using appropriate personal protective equipment and clothing • avoid inhaling; work in well-ventilated area and/or wear respiratory protection • store in designated areas
Class D - Division 3 **Biohazardous and Infectious Materials**	• may cause a serious disease resulting in illness or death	• take every precaution to avoid contamination • handle only when wearing necessary protective equipment • handle in designated areas only where appropriate engineering controls are in place
Class E - Corrosive Materials	• causes severe eye and skin irritation upon contact • causes severe tissue damage with prolonged contact • may be harmful if inhaled • may damage metal	• keep containers tightly closed • avoid skin and eye contact by wearing eye, face and hand protection and protective clothing • avoid inhaling; work in well-ventilated area and/or wear respiratory protection

Class F - Dangerously Reactive Materials	• unstable; may react with water to release toxic or flammable gas • may explode as a result of shock, friction or increase in temperature • may undergo vigorous polymerization	• keep away from heat • open containers carefully; do not drop • store material in designated cool, flame-proof area

Taken from Laboratory Health and Safety Handbook – WorkSafe BC

4.2 Class A- Compressed Gases and Cryogenic Materials

i. Definition

Class A - compressed gases include compressed gases, dissolved gases or gases liquefied by compression or refrigeration within reinforced metal cylinders. This includes cryogenic liquids that are hundreds of degrees below zero Celsius, thereby representing an extreme cold hazard. There are four sub-groups of compressed gases: Compressed gas (O_2, helium, argon); compressed liquid (chlorine, CO_2); dissolved gas in liquid (acetylene in acetone), and cryogenic liquids (N_2, O_2).

ii. Hazards

Compressed gases present a physical danger resulting from the sudden, out-of-control release of these materials from their containers. This release is associated with a concomitant discharge of energy due to great expansion in volume of the material leaving the cylinder (i.e. the energy released is akin to a jettisoned rocket that is capable of bursting through walls or any other objects in its way). The rapid diffusion of compressed gas can increase the exposure radius, increasing the potential for acute exposure and damage (corrosive or toxic gases). The release of compressed gas can also cause asphyxiation through the displacement of oxygen in the air. Compressed gases may be flammable, pyrophoric, toxic, corrosive, oxidizer, or reactive; their additional hazards will depend on the chemical nature

Cryogenic Liquids:

Most cryogenic liquids, such as liquid nitrogen, can cause frostbite to the skin. A few cryogenic liquids, such as hydrogen, propane and liquefied natural gas, are flammable. When handling these materials, the appropriate hand and eye protection against cold hazards as well as chemical hazards must be used.

iii. Handling

The following are basic precautions should be implemented when handling compressed gas cylinders:

- Chain or strap in upright position
- Protective cap in place while being moved
- Use cart to move
- Do not empty (not less than 30 psi)
- Cylinder valves closed when not in use

Compressed Gas Cylinders – Pressure Regulators
Pressure regulators are used in a system using compressed gas to reduce pressure from high-pressure sources, such as gas cylinders or gas supply pipelines, to a safe working pressure range. The pressure regulator should be attached to a cylinder without forcing the threads. A poor fit may indicate that the regulator is not intended for use on the gas chosen.

Take additional precautions when working with cryogenic liquids:

- Use proper Personal Protective Equipment
    - Wear clothing that cover arms & legs
    - Wear cryogenic gloves under sleeves
    - Wear safety glasses and face shield
    - Wear non-slip closed shoes and apron
- Use specially designed storage, transport, and dispensing containers
- When working indoors, make sure the dispensing area is adequately ventilated

Insulated vacuum jacketed pressure vessels are equipped with safety relief valve and rupture disk to protect from pressure build up, check them regularly.

When transporting large volume of cryogenic liquids in an elevator, whenever possible, send the cryogen container in an elevator without any passengers, and ensure that no passengers get on the elevator while the cryogen is being transported. In a power failure, a passenger could be trapped in the confined space of an elevator with the cryogen. Excessive amounts of the cryogen could vaporize and displace the oxygen

Please see the procedures for the Working Safely with Hazardous Gases.

4.3 Class B- Flammable and Combustible Materials

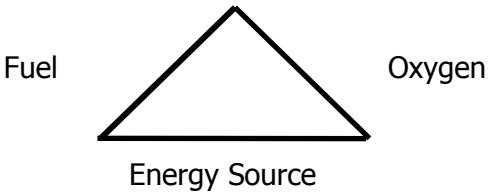
i. Definitions

Class B - flammable and combustible materials are substances that form vapours that can burn or explode. Vapour pressure is the pressure that is exerted by a saturated vapour above its own liquid in a closed container. It is reported in mm Hg, and it is positively correlated with temperature.

Examples of substances that are included in this classification are:

- Flammable gases
- Flammable liquids
- Combustible liquids
- Flammable solids
- Flammable aerosols
- Reactive flammables (spontaneously combustible in air, or materials that react with water to produce a flammable gas)

There are three elements that must be present in order for a fire to result. One way of pictorially describing this phenomenon is the "Fire Triangle". Removing any of the three components will extinguish a fire.



The use, storage and handling of flammable and combustible materials are governed by WorkSafeBC and the BC Fire Code.

"**Flash point**" defines the minimum temperature at which a liquid within a container gives off vapour of sufficient concentration in air that can ignite in the presence of an ignition source.

A "**flammable liquid"**, as per the BC Fire Code, is "a liquid having a flash point below 37.8°C (100°F), and having a vapour pressure not exceeding 275.8 kPa (absolute) at 37.8°C".

A "**combustible liquid"** is one with a flash point at or above 37.8°C.

"**Explosive limits**" refers to the vapour concentration range of a combustible or flammable material that will ignite in the presence of an ignition source.

The "**auto-ignition temperature**" is the temperature at which the vapour from a liquid will ignite without a source of ignition such as a spark or flame.

ii. Hazards

May readily burn or explode if placed near heat, sparks, or open flames.
Flammable liquids give off vapours that, in most cases, are heavier than air and can travel long distances until reaching a source of ignition such as an open flame, hot surfaces, static sparks, etc. at which time a fire or explosion could result. These vapours can also be carcinogenic or otherwise harmful to one's health, and should generally be used in a fume hood.

Flammable liquids pose many serious problems. The misuse of a small amount can have a disastrous effect. As liquids, they can flow and thus any spillage will increase the fire hazard. Burning flammable liquids will likewise flow and spread the fire.

iii. Handling

Keep away from heat, sparks, and open flames. Keep the minimum quantity in the work area. Store the chemicals away from oxidizers. Label containers FLAMMABLE. Ensure sprinklers and fire extinguishers are available and working. Safe handling practices must be strictly followed in handling and transferring of all flammable liquids.
Grounding of containers used for transferring flammable solvents is required to eliminate static charge build-up.

Because vapours continuously escape from flammable liquids, they must be kept in closed or covered containers. In the **open** laboratory area, the UBC Flammable Liquid Guidelines restrict the volume of flammable liquids to a maximum of 25 L. Amounts in excess of this must be kept in approved safety cans, a flammable liquid cabinet or proper flammable storage facility.

The flash points of several commonly used solvents are provided in Appendix A.

4.4 Class C- Oxidizing Materials

i. Definition

Class C – oxidizing materials are substances that readily yield oxygen or its equivalent to stimulate the combustion (oxidation) of organic matter. Chromic acid and chromates, nitric acid and nitrates, perchloric acid and perchlorates, permanganates, peroxides and bleach (hypochlorite) are all examples of oxidizing reagents. Oxidizers are incompatible with reducing agents (which usually contain hydrogen), such as hydrides, bisulfites and thiosulfates, and with flammable and combustible materials such as solvents, Varsol and acetic acid.

Nitric and perchloric acids are both strongly oxidizing acids. They will act rapidly on exposed skin through a denaturing mechanism. Nitric and perchloric acids will also act explosively with organic compounds and reducing agents.

ii. Hazards

Oxidizing materials can cause fire without an ignition source when mixed with flammable or combustible materials. These materials can also increase the speed and intensity of a fire. And cause generally non-combustible materials to burn rapidly. Oxidizing materials may react with other chemicals to produce toxic gases as well.

iii. Handling

Oxidizing materials should be used in an area free of combustible, flammable and reducing materials. Minimum amounts of oxidizing material should be left out of storage when in use. Oxidizing materials that contain peroxidizable compounds must have a label (see Special Hazardous Chemicals section), and must be tested regularly to ensure that a build up of peroxide has not occurred.

4.5 Class D- Toxic Material

i. Definition

A toxic chemical is any substance that may cause damage to structure or disturbance to function when it is ingested, inhaled or absorbed, or when applied to, injected into or developed within the body, in relatively small amounts, by its chemical action.

Class D – toxic and infectious materials comprise 3 subdivisions. D1 materials are those causing immediate and serious toxic effects including coma and death. D2 materials are those that cause effects over a longer period of time. These materials can be carcinogenic (causing cancer), teratogenic (causing birth defects), mutagenic (causing mutation in DNA), irritating or sensitizing, bringing about chronic effects. D3 materials are those classified as biohazardous and will not be discussed here. Please refer to the

Laboratory Biosafety manual for detailed information on the use, handling and storage for these materials.

The effects of toxic chemicals are related to the routes of entry, dose, and duration.

ii. Routes of Entry

Skin and Eyes

a. Interaction
    - Skin acts as a barrier
    - Reaction with a chemical may cause local irritation or tissue destruction
    - A chemical may penetrate the skin and react with tissue proteins causing allergic sensitivity
    - A chemical may penetrate the skin and enter the blood stream, especially through broken skin
    - Fat soluble solvents readily penetrate the skin
    - Eyes are especially vulnerable to chemical exposure

b. Symptoms of Exposure
    - Dry, whitened skin
    - Redness, swelling
    - Rash, blisters, itching

c. Protection
    - Protect hands against cuts
    - Wear the appropriate gloves, remove gloves before touching uncontaminated surfaces
    - Protect eyes with safety glasses, goggles, or face shield

Respiratory Tract

a. Interaction
    - Route of entry for gases, vapours, and small particulates
    - Absorption of gases and vapors in the respiratory tract depends on
        - Vapor pressure of the material
        - Concentration in inhaled air
        - Chemical properties

b. Symptoms of Exposure
    - Headache
    - Eye, nose, and throat irritation
    - Increased mucus in the nose and throat
    - Narcotic effects (headache, confusion, dizziness, collapse)
    - Asphyxiation through displacement of oxygen or blocking transport or utilization of oxygen (e.g. carbon monoxide, hydrogen sulfide)

c. Protection
    - Engineering controls such as fume hoods, general and local exhaust systems, and biosafety cabinets
    - When engineering controls are not available, use respirators to eliminate exposure from inhaled particulates, vapors, gases or fumes

- There are different types of respirators and filters, see the Hazard Controls section

Gastrointestinal Tract

a. Interaction
    - Ingestion of toxic substances can occur accidentally through poor hygiene practices or use of contaminated laboratory glassware for food or drink

b. Symptoms
    - Mouth and throat discomfort
    - Gastrointestinal discomfort
    - Coma, death

c. Protection
    - Do NOT pipette by mouth
    - Do NOT store food items in lab glassware bin or lab refrigerator
    - Do NOT eat or drink in the lab
    - Wash hands after working with chemicals, before leaving the lab and before eating

Injection

a. Interaction
    - Occurs through mishaps with hypodermic needles and broken glassware

b. Symptoms
    - May be local or systemic

c. Protection
    - Wear protective gloves when feasible
    - Use forceps or broom and dustpan for cleaning up broken glass

iii. Dose

The dose is the amount of chemical that actually enters the body. It can be determined by the concentration of the chemical and frequency and duration of exposure.

iv. Duration of exposure

Acute Exposure

- Usually single, short term exposure
- Acute toxicity results from the potential for a chemical to cause harm after a single, short exposure.
- Effects appear quickly
- Effects often reversible

Chronic Exposure
- Repeated exposure
- Chronic toxicity is the potential for a chemical to cause harm following repeated exposure over weeks, months or years
- Effects take time to appear
- Usually irreversible effects
- e.g. mercury and carbon tetrachloride are cumulative poisons requiring special work and clean-up procedures

v. Effects of Toxic Chemicals

The effect of toxic chemicals can be local or systemic and will depend on individual worker susceptibility.

Local effects
- Area in contact with the chemical (e.g. acid, base burns)

Systemic effects
- Affects tissues and organs that are far removed from the site of contact
- Chemical enters body and is distributed via blood
  e.g. methanol inhalation or ingestion can cause permanent eye damage

Individual Susceptibility
- Important factors include general health, heredity, diet, age, and sex

The properties of the chemicals being used must be determined prior to use by reading labels and Material Safety Data Sheets.

Any substance has the potential for being toxic depending on:
- The amount or dose;
- Duration of exposure;
- The route of entry; and
- Susceptibility of the individual being exposed.

vi. Exposure Limits

Definitions:
- "8-hour TWA limit" means the time weighted average (TWA) concentration of a substance in air which may not be exceeded over a normal 8 hour work period;
- "ACGIH" means the American Conference of Governmental Industrial Hygienists publication entitled Threshold Limit Values and Biological Exposure Indices as amended from time to time, or
- "Short-term exposure limit" or "STEL" means the time weighted average (TWA) concentration of a substance in air which may not be exceeded over any 15 minute period, limited to no more than 4 such periods in an 8 hour work shift with at least one hour between any 2 successive 15 minute excursion periods;
- "Ceiling limit" means the concentration of a substance in air which may not be exceeded at any time during the work period;
- ACGIH L endnote- "L" is defined as "exposure by all routes should be carefully controlled to levels as low as possible." Examples of these highly toxic substances include benzo(a)pyrene, polytetrafluoroethylene decomposition products, and rosin core solder thermal decomposition products.

Workers must not be exposed to a substance concentration that exceeds the ceiling limit, short-term exposure limit, or 8-hour TWA limit prescribed by ACGIH.
If a TWA, STEL or other exposure limit is not available, there are other toxicity measures:

- LD50: "Lethal Dose" the amount of a material given at once, which causes the death of 50% of a group of test animals (units in mg/kg)
    - Extremely Toxic -1 or less (a drop)
    - Highly Toxic- 1-50 (4 ml)
    - Moderately Toxic- 50-500 (30 ml)
    - Slightly Toxic 500- 5000 (600 ml)
    - Practically Non-toxic- 5000 and above

- LC50: for inhalation experiments, the concentration of the chemical in air that kills 50% of the test animals in a given time (usually four hours) (units in ppm)
    - Extremely Toxic -10 or less
    - Highly Toxic- 10-100
    - Moderately Toxic- 100-1000
    - Slightly Toxic 1000- 10000
    - Practically Non-toxic- 10000 and above

More information on toxicity classes and relative amounts/concentrations can be found on the CCOHS website.

Delayed effects:
If a substance identified as any of the following is present in the workplace, it must be replaced if practical, with a material, which reduces the risk to workers:
(a) **ACGIH A1**- Confirmed human carcinogen or **ACGIH A2**- Suspected human carcinogen, or **IARC 1**- Human carcinogen, **IARC 2A**- Probable human carcinogen or **IARC 2B** - Possible human carcinogen, or **NTP**- Known to be Human Carcinogen (KC) or **NTP**- Reasonably Anticipated Human Carcinogen (RAC).
(b) **ACGIH reproductive toxin**- a substance that has the potential for an adverse reproductive effect, including effects on both female and male reproductive organs, tissues, or cells; effects on fertility; effects on the embryo or fetus; effects that have been demonstrated to cause developmental abnormalities; tumour-causing effects; and effects on the newborn.
(c) **ACGIH sensitizer**- This critical health effect refers to the potential for a substance to produce sensitization as confirmed by human or animal data. Depending on the substance, workers can become sensitized to the substance through the respiratory system, the skin, or the eyes. Sensitization often involves a response by the body's immune system. Initially, there may be little or no response to a sensitizing substance. However, after a person is sensitized, subsequent exposure may cause severe reactions even at low exposure concentrations, including at levels below the exposure limit.

IARC- International Agency for Research on Cancer
ACGIH- American Conference of Governmental Industrial Hygienists
NTP- National Toxicology Program

See Appendix B for a list of confirmed or probable carcinogens, reproductive toxins and sensitizers.

If it is not practicable to substitute with a material, which reduces the risk to workers, an exposure control plan must be maintained to ensure workers' exposure as low as reasonably achievable below the exposure limit established.

For the Table of Exposure Limits for Chemical and Biological Substances, refer to the WorksafeBC BC OHS regulations.

Additional information can be found in the MSDS of specific chemicals.

4.6 Class E- Corrosive Materials

i. Definition

Class E - corrosive substances are materials that, upon contact, cause visible destruction of, or irreversible alteration to tissue or metal. The eyes are especially sensitive to permanent damage by corrosive substances.

ii. Hazards

Large quantities of corrosive chemicals are used routinely in manufacturing and laboratory procedures. Many household chemicals are corrosive in nature and deserve the same respect and care.

Corrosives comprise both acids and bases (caustics). The pH of a solution describes the degree of acidity or alkalinity of a solution, on a scale of 0 to 14. Materials with pH 7 are considered neutral and non-corrosive; those below 7 are acidic and those above 7 are caustic or basic. The further away from pH 7 that a substance is, the more corrosive it is.

iii. Handling

When mixed together, acids and bases will react vigorously with each other through an exothermic (heat releasing) neutralization reaction. Proper handling and usage of corrosives require protective clothing to prevent skin, eye, or lung exposure. Serious burns and eye or lung damage can result from contact with corrosive materials.

Exposure requires immediate action to wash away the material away with copious amounts of water. Thick, oily corrosive liquids such as sulphuric acid and 40% sodium hydroxide are especially hazardous as it is difficult for water to quickly penetrate and dissolve these materials. Washing, in this situation, may include wiping off the oily layer with a cloth while keeping the affected body part in the water stream. Proper and prompt decontamination can prevent or minimize serious injury.

Volatile corrosive materials, such as concentrated ammonium hydroxide or hydrochloric acid, should be handled in the fume hood. Personal protective equipment, such as splash goggles, rubber gloves, substantial shoes and a lab coat or rubber apron, should always be worn when handling corrosive materials.

Acids
The common inorganic acids include hydrochloric, nitric, sulphuric, and phosphoric acids. Phenols and the halogens, such as bromine and chlorine are also acidic in nature. All hydrogen halides are acids that are serious respiratory and skin hazards.

Sulphuric acid is a very strong dehydrating acid. When preparing aqueous solutions of this oxoacid and other concentrated acids, ***always add acid to water***, very slowly. The reaction is extremely exothermic, producing a rapid increase in temperature during mixing. Continual stirring of the solution as well as the use of "distilled water" ice for cooling (substitute for water) is recommended.

Hydrogen fluoride presents a special hazard. Both the gas and liquid form are highly toxic and able to penetrate deeply into the tissues and bone. Symptoms (pain) of contact with hydrogen fluoride solutions (eg. Hydrofluoric Acid) may be delayed with serious burns resulting. When skin is exposed to hydrogen fluoride solutions, flush with water for at least 15 minutes, apply calcium gluconate gel after washing with water, and in all cases of exposure, seek medical attention. See UBC procedures for the Safe Handling of Hydrofluoric Acid.

Bases (caustics)
The most common bases found in laboratories are the alkali metal hydroxides, ammonium hydroxide and organic amines. The alkali metal hydroxides are especially destructive to the skin. The skin has a *slippery feel* when exposed to these materials because the hydroxyl radicals bond to the skin's peptides (*saponification*). Since the pain of exposure is delayed, it is extremely important that the skin be washed thoroughly for at least 15 minutes after exposure to these alkali solutions. The vapours from ammonium hydroxide (ammonia) present serious respiratory hazards.

4.7 Class F- Dangerously Reactive Materials

i. Definition
Class F - Dangerously reactive materials are substances that:
a) undergo vigorous polymerization, decomposition or condensation;
b) become self-reactive under conditions of shock, or increase in pressure or temperature; or
c) react vigorously with water to release poisonous gas.
d) spontaneously combust in air (pyrophoric)

See Appendix C for a list of Dangerously Reactive Materials.

ii. Hazards and Handling
WorksafeBC BC OHS Regulation 30.20 states that:
a) Quantities of explosive and highly reactive material available in the work area must be restricted to amounts immediately required for the work day;
b) If the nature of the laboratory work suggests that explosions or implosions may result, the laboratory apparatus or equipment involved in such work must be adequately shielded;

c) Subsequently, the operators must be provided with and must wear suitable protective devices; and
d) Wherever practicable, the work must be safely isolated from workers by distance.

Acid halides, such as acetyl chloride or phosphoryl chloride, react violently with water. Lithium aluminium hydride and butyl lithium spontaneously combust in air. Some organic monomers, such as butadiene, will self-polymerize in air. Read labels and material safety data sheets carefully to determine reactivity and compatibility characteristics of the chemicals being used. See the Safe Handling Procedures for Pyrophoric Materials.

Potentially Explosive chemicals –can release tremendous amounts of destructive energy rapidly. If not handled properly, these chemicals can pose a serious threat to the health and safety of laboratory personnel, emergency responders, building occupants, chemical waste handlers, and disposal companies.

Most chemicals that are used in research and teaching laboratories are stable and non-explosive at the time of purchase. Over time, some chemicals can oxidize, become contaminated, dry out, or otherwise destabilize to become Potentially Explosive Chemicals (PEC) (e.g., isopropyl ether, sodium amide, and picric acid).

PECs are particularly dangerous because they may explode if they are subjected to heat, light, friction, or mechanical shock. For PECs disposal, the UBC campus uses a special contractor, the special care and special procedures require for these chemicals result in high disposal cost - $425 for each container.

See Appendix D:
- Explosives and Potentially Explosive Chemical Families (with examples)
- Chemicals That May Deteriorate to Hazardous Conditions
- Chemicals That May Explode Due to Over Pressurized Container

Before ordering new chemicals:

Review the attachments and the chemical's MSDS. If the material you are about to purchase is a potentially explosive material:
- Consider substituting it with less hazardous material
- If substitution is not practical purchase the smallest amount possible
- Limit storage duration

Contact HSE at 7-8821 to arrange for special disposal

For storage and handling requirements refer to MSDS of the specific material.

4.8 Special Hazardous Chemicals

Organic Peroxides

i. Definition
Organic peroxides are a particular group of oxidizing materials that are often unstable in nature. They can be among the most hazardous materials handled in laboratories. They are low power explosives, which are sensitive, to varying degrees, to heat or shock. Often they are products of room temperature oxidation of a variety of organic ethers, alkenes, certain alcohols, potassium and other materials. Organic peroxides are especially dangerous when dried.

Peroxide inhibitors are usually added to compounds that readily form explosive peroxides; however, they may not be sufficient to control peroxide formation once the container has been opened. Any peroxidizable compound must have this label attached to the container. The label should be updated every 3-12 months depending on the chemical.

PEROXIDIZABLE COMPOUND

Rec'd **Opened**

Date

Discard or test within _____ months after opening

Test Dates _____

Test Results _____

A list of Peroxidizable compounds is found in Appendix E.

ii. Precautions
If ether peroxidation is visibly evident as a viscous layer in the bottom of the container or crystals around the cap, **do not handle the container**. If the container is more than 2 years old, and has not been opened or tested within the past 12 months, do not open the container and call HSE at 7-8821.

iii. Peroxide Testing Program
Certain ethers such as di-isopropyl ether form peroxides more rapidly than most others and should be handled with particular care. Purchases of large quantities and long term storage are not recommended.

There are several methods for the detection of peroxides, two of which are described below.

Test Strips
The simplest method for testing for the presence of peroxides in materials can be done using peroxide test strips available from local laboratory supply houses (e.g. E M Quant from Anachemia Scientific).

Chemical Testing
To 1 mL of the ether to be tested, add a solution of 100 mg of potassium iodide in 1 mL of glacial acetic acid. A pale yellow colour indicates a low concentration (0.001 to 0.0005 %) of peroxides, and a bright yellow or brown colour indicates a high (> 0.1%) and hazardous concentration of peroxides. This chemical test is more sensitive than the test strips, as it will detect dialkyl peroxides as well as hydroperoxides.

It should be remembered that these tests are valid only for relatively simple chemicals. Complicated organic structures may also act as oxidizing agents and therefore appear to give positive tests for peroxides. There are no testing methods for peroxides of potassium metal.

iv. Handling and Removal of Peroxides
If peroxides are detected, the solvent should be treated prior to use or being sent for disposal to HSE. See UBC's Procedures for Handling and Removing Peroxides.

Picric Acid

Dry ***picric acid*** is a highly explosive material that is widely used as a DNA marker. Section 30.22 of the WorksafeBC BC Regulation states that "solid picric acid must be stored with at least 10% moisture content and **regular inspections** must be made to ensure that the minimum **moisture content is maintained**. Solutions of picric acid must not be allowed to accumulate and dry around cap threads". It is important to: dispose of old stocks; order minimum amounts; and check current stocks routinely to ensure solid material has not dried out. **Do not handle dry picric acid** containers; call HSE for advice.

Perchloric Acid

Section 30.21 of the WorksafeBC BC OHS Regulation specifically refers to the use of ***perchloric acid***. Perchloric acid must be used in a special wash-down fume hood made of a non-combustible material (usually stainless steel). The use of the hood must be posted and no combustibles are permitted to be stored in the same hood. **No more than 6.4 kg of perchloric acid may be stored in a laboratory**. Stored perchloric acid **must be inspected monthly**, and if any discoloration is noted it must be disposed of immediately and in a safe manner. Anhydrous perchloric acid may only be used if freshly made; any unused portions must be disposed of safely at the end of the procedure and not kept for more than one day. See the procedures for Pechloric Acid Use in the Laboratory for details.

V. Hazard Controls

5.1 Introduction

At UBC there are many types of laboratories, each with very different hazards, however common control measures can be implemented to prevent accidents, injuries, and disease. The following process can be used to address common laboratory health and safety hazards:

5.1.1 Identify and assess hazards

Supervisors are required to identify hazards and conduct a hazard assessment before any equipment, machinery, or work process is used or started. Potential hazards include exposure to chemicals, heat, noise, vibration, violence, and ergonomic problems. The hazard assessment should be done in consultation with a health and safety committee member or, if there is no committee, a person who is familiar with the job process. A hazard assessment guide can be found in Appendix F.

5.2.2 Implement control measures

Once the hazards have been identified and assessed, it is necessary to control these chemical hazards used in the laboratory. There are four types of controls for minimizing or eliminating hazards:

- Substituting with less hazardous material
- Engineering controls
- Administrative controls
- Personal protective equipment

Elimination of a hazardous product or substitution with a less hazardous product represents the best solution. Engineering controls are the next best choice for controlling hazardous materials. They do not require continual monitoring and are more likely to be used; however, they do require regular maintenance and are more expensive to implement. The next type of control is administrative and it includes written procedures, training, supervision and scheduling of activities. The use of personal protective equipment represents the least effective type of control; its effectiveness is limited by the dependence on individuals wearing it, and its discomfort.

5.2 Engineer Controls

5.2.1 Laboratory Fume Hoods

Fume hoods protect workers from hazardous exposure to airborne contaminants by capturing fumes, dusts, vapours and gases generated inside the hood and discharging them safely.

i. Work Practices

- Conduct all operations, which generate air-born contaminants, inside a fume hood.
- Always wear appropriate eye protection and a lab coat when working near a fume hood.
- If the hood is used for long-term experiments, post the name and phone number of the person in charge, experiment title and potential hazards.

- Keep your head outside the face of the hood with the sash lower than your face.
- Keep apparatus at least 15 cm from the face of the hood to minimize turbulence at entrance to hood as this can cause some of the contaminants to be swirled out of the hood.
- Avoid blocking the rear ventilation slot. Material stored at the back of the hood should be stored on an elevated shelf so that the slot airflow is not impeded.
- Avoid storing chemicals or gas cylinders inside the hood. Hazardous chemicals should be stored in approved safety cabinets.
- Do not place electrical receptacles or other ignition sources inside the hood when flammable liquids or gases are present. No permanent electrical receptacles are permitted in the hood (current design criteria).
- Avoid cross drafts at the face of the hood. Minimize foot traffic past the hood and position windows and supply air diffusers to direct air away from the hood.
- Do not raise the sash higher than the labeled height as this will reduce the hood efficiency.
- Leave the sash lowered when the experiment is unattended.
- Keep the bypass grill clean.

ii. Fume Hood Airflow Failure Response

The abrupt and complete loss of airflow to a laboratory fume hood may create significant hazards or cause injury to maintenance and laboratory staff. The purpose of this procedure is to ensure that the hazards associated with hood system failure are minimized.

Fume hood users need to develop a plan of action to follow if the fume hood fails. This planned procedure should include the following steps:

If Fume Hood Air Flow Stops:

- Note pressure gauge reading, if one is provided.
- Shut off experiments, turn off heat, relieve system pressure.
- Seal containers; remove compressed gas cylinders from the hood.
- Ensure no other lab equipment is vented into the hood.
- Place "Do Not Use; Hood Out of Order" sign on the fume hood.
- Where radioisotopes are used, contact the Radiation Officer at 2-7052.
- Call Trouble Calls @ 7-9272.
- Advise your departmental administrator

iii. Fume Hood Maintenance

Fume hood maintenance is a planned, annual procedure. Depending on the nature of the work involved (e.g. whether the actual fume cupboard is included or whether the fume hood system has leaks or not) there are standard procedures that must be performed by fume hood users prior to work being done by maintenance personnel.

There are three levels of fume hood maintenance; they differ with respect to the type of work or maintenance being done and consequently with respect to the activities to be assumed by the fume hood user. For all fume hood shutdowns, the following is required:

- Containers capped; gas cylinders removed
- Heat sources closed
- Hood monitored for radioactivity & decontaminated as required
- No equipment is venting into hood.

The table below summarizes the main differences between Level II & III.

Type of Work or Maintenance	User's Responsibilities
II. Work done outside hood, but within ductwork	All chemicals removed from hood
III. Work done within hood	Everything is removed from hood

5.3 Personal Protective Equipment

Personal protective equipment is an individual's means of protecting themselves from hazards in the laboratory. Wherever possible, engineering controls should be installed to make the workplace safe.

PPE needs and selection must be determined based on assessment of exposure hazard, the available control measures and the need for further controls. PPE must be selected and used in accordance with recognized standards, and provide effective protection. Personal protective equipment must be provided by employer if it is required to perform an operation safely. Hazards must be assessed before the proper PPE can be chosen. Refer to Appendix G for a chart of hazard considerations and the appropriate PPE selection.

The basic PPE to be used in a laboratory where chemicals are used consists of: lab coat, safety eyewear, appropriate gloves, long pants, close-toe and heel shoes.

The type of PPE that is required will depend on the particular hazards of the materials, equipment and procedures being used and may include: safety headgear, eye and face protection, limb and body protection, and foot wear. In addition respiratory protection may be required if the safe exposure limits are to be exceeded and ear protection should be used in environment where noise level TWA exceed 85 dB.

i. Eye Protection

The type of eye protection that is required in a laboratory depends on the materials and operations in use. Proper eye protection includes safety glasses, safety goggles, and face shields. Eye protection will be required when there is hazard from:

- flying particles (dust)
- liquid chemicals (acids and caustics)
- gases and vapors
- and injurious light (UV or IR radiation)

The following guidelines should be considered when determining the type of eye protection that is required. The same rules apply to those working near or visiting hazardous areas.

1) Contact lenses are not recommended when working with volatile chemicals. They must be worn with safety glasses and supervisors must be aware of who is wearing them.
2) Shatterproof prescription eyeglasses do not provide adequate splash protection. Splash goggles, with sealed sides and top, must be worn when handling corrosive, toxic or irritating liquids and there is a splash risk.
3) Face shields and explosion-proof shields must be used where necessary; i.e. use when there is a risk of explosion, splashing or combustion with high or low temperature or during pressure reactions or procedures.

ii. Gloves

There are several glove types available depending on the potential hazard of concern. Hand protection will be required when there is a risk of: chemical burns, hazardous material skin absorption. When work involves: sharp objects, material cutting, or extreme temperature

No single glove material will protect against all chemicals. Different glove materials interact differently with different types of chemicals. It is therefore important to match the right glove material to the type of chemical(s) being used. Natural rubber latex gloves may be suitable for dilute aqueous solutions; however, oils, greases and many organic solvents will easily permeate the latex material. Nitrile gloves may be used against oils and greases but are generally unsatisfactory for use against aromatic or halogenated solvents.

Suppliers and manufacturers sometimes publish chemical compatibility charts or refer to the MSDS to help identify the most suitable glove type for specific applications.

General guidelines for chemical resistant glove selection are included below. Due to variations between manufacturers, the final choice must be dependent on their specific characteristics and recommendations.

The Occupational Health and Safety Administration (OSHA) provides the following general guidelines for glove compatibility and selection:

Leather, Canvas or Metal Mesh Gloves - Sturdy gloves made from metal mesh, leather or canvas provide protection against cuts and burns. Leather or canvass gloves also protect against sustained heat.

Fabric gloves protect against dirt, slivers, chafing and abrasions. They do not provide sufficient protection for use with rough, sharp or heavy materials. Adding a plastic coating will strengthen some fabric gloves.

Chemical- and Liquid-Resistant Gloves
Chemical-resistant gloves are made with different kinds of rubber: natural, butyl, neoprene, nitrile and fluorocarbon (viton); or various kinds of plastic: polyvinyl chloride (PVC), polyvinyl alcohol and polyethylene. These materials can be blended or laminated for better performance. As a general rule, the thicker the glove material, the greater the

chemical resistance but thick gloves may impair grip and dexterity, having a negative impact on safety.

Some examples of chemical-resistant gloves include:

Butyl gloves are made of a synthetic rubber and protect against a wide variety of chemicals, such as peroxide, rocket fuels, highly corrosive acids (nitric acid, sulfuric acid, hydrofluoric acid and red-fuming nitric acid), strong bases, alcohols, aldehydes, ketones, esters and nitro compounds. Butyl gloves also resist oxidation, ozone corrosion and abrasion, and remain flexible at low temperatures. Butyl rubber does not perform well with aliphatic and aromatic hydrocarbons and halogenated solvents.

Natural (latex) rubber gloves are comfortable to wear, which makes them a popular general-purpose glove. They feature outstanding tensile strength, elasticity and temperature resistance. In addition to resisting abrasions caused by grinding and polishing, these gloves protect workers' hands from most water solutions of acids, alkalis, salts and ketones. Latex gloves have caused allergic reactions in some individuals and may not be appropriate for all employees. Hypoallergenic gloves, glove liners and powderless gloves are possible alternatives for workers who are allergic to latex gloves.

Neoprene gloves are made of synthetic rubber and offer good pliability, finger dexterity, high density and tear resistance. They protect against hydraulic fluids, gasoline, alcohols, organic acids and alkalis. They generally have chemical and wear resistance properties superior to those made of natural rubber.

Nitrile gloves are made of a copolymer and provide protection from chlorinated solvents such as trichloroethylene and perchloroethylene. Although intended for jobs requiring dexterity and sensitivity, nitrile gloves stand up to heavy use even after prolonged exposure to substances that cause other gloves to deteriorate. They offer protection when working with oils, greases, acids, caustics and alcohols but are generally not recommended for use with strong oxidizing agents, aromatic solvents, ketones and acetates.

A visual inspection of gloves should be done before each use to ensure that they are not torn, punctured or made ineffective in any way. Gloves that are discolored or stiff may also indicate deficiencies caused by excessive use or degradation from chemical exposure.

Any gloves with impaired protective ability should be discarded and replaced. Reuse of chemical-resistant gloves should be evaluated carefully, taking into consideration the absorptive qualities of the gloves. A decision to reuse chemically-exposed gloves should take into consideration the toxicity of the chemicals involved and factors such as duration of exposure, storage and temperature.

iii. Protective Clothing

Lab coats must be worn in laboratories at all times as per WorkSafeBC Regulations. Additional protection such as aprons and specialized suits may be required when handling corrosive, toxic, or other harmful materials. It is important to choose the material best suited for the work being done. Lab coats and coveralls should be made of a tough fire-resistant fabric with proper fasteners and long enough to protect the

legs. Aprons should be chemical-resistant, fire-resistant and washable. Avoid flammable fabrics such as polyester. Bare legs are not allowed when handling hazardous materials.

iv. Footwear

Shoes must be worn in the laboratory; they must cover the entire foot and be made of a substantial material, such as leather. Open-toed shoes and sandals must not be worn by laboratory workers who work with or near chemical hazards. Workers performing spill clean up require chemical-resistant footwear. Workers who frequently change gas cylinders are at increased risk of injury from cylinders falling on their toes, therefore hard-toed shoes are recommended for this task.

v. Respiratory Protection

In general, it should not be necessary for laboratory workers to wear respiratory protection. Workers must know the limitations of the respirator and be properly fit-tested for the use of them. Use of respirators should be considered to control exposure **only** after engineering and administrative controls have been considered. These types of controls include ventilation (e.g. fume hoods), enclosing the process, substitution of less hazardous products, rescheduling of work procedures, etc.

Users that are required to wear respirators at the University of British Columbia must contact Risk Management Services prior to wearing a respirator.

A **respirator program** is required to ensure that respirators used by employees provide effective protection against airborne contaminants. It should also define employer, supervisor and employee's respective responsibilities. Contact Health Safety and Environment if a respirator is required.

VI. Chemical Storage and Segregation

6.1 Inventory

An annual inventory of hazardous materials is required. According to the WorkSafeBC Occupational Health and Safety Regulation, Part 5, Section 5.98, "An inventory must be maintained which identifies all hazardous substances at the workplace in quantities that may endanger workers in an emergency including controlled products covered by WHMIS, explosives, pesticides, radioactive materials, hazardous wastes, and consumer products. The inventory must identify the nature, location, and approximate quantity of all such substances, and the location of MSDSs."

Annual inventories serve as a reminder to:
- Check chemicals with limited shelf life;
- Remove surplus and old chemicals;
- Correct incompatible storage;
- Know what you have; and
- Cleanup containers & shelves.

Develop a system for locating your chemicals and finding information about them such as:
- Computer database system
- Cardex system

A good system should:
- Direct you quickly to the chemical;
- Be easy to use;
- Be easy to maintain; and
- Be updated annually.

Laboratories are not storerooms, particularly with respect to chemicals and solvents. Chemicals in laboratories should be stored in areas away from experimental activities, and limited to the requirements of 12 months or less. Excess stock should be kept in a proper chemical storage facility.

Order in small amounts; don't stockpile chemicals. It is often false economy to order 1 kg of a material because it is cheaper than ordering 100 g of the same product. The materials end up:
- Taking up valuable space;
- Presenting a greater potential hazard;
- Eventually becoming a disposal problem, and costing the generator more to dispose of the material.

6.2 General Rules for Safe Storage

Chemical storage, whether in a laboratory or central storeroom, should be under the supervision of a qualified person; storerooms must have adequate security. Specialized cabinets should be used for specific groups of compatible substances.

- Do not overcrowd shelves.
- Store solvents in a proper flammable liquid cabinet and keep door closed.
- Use appropriate containers for solvents and waste.
- Store highly toxic or controlled materials in a secure (locked) cupboard.
- Store in central, properly ventilated area that includes forced ventilation from floor to ceiling and with exhaust above roof level.
- Store working quantities (small containers that are used daily or frequently) on bench side shelving
- Shelving should be accessible with chemicals at eye level or lower; no high shelf chemical storage.
- Avoid floor chemical storage (even temporary).
- Shelf assemblies are firmly secured to walls.
- Provide anti-roll lips on all shelves.
- All chemical containers must be sealed, intact, properly labeled and made of compatible material
- Regularly vent materials capable of building up pressure; e.g. formic acid, nitric acid, and hydrogen peroxide
- Do not store chemicals in fume hoods unless the fume hoods are used exclusively for this purpose and are labeled as a storage area only

6.3 Chemical Segregation for Storage

Each chemical must be evaluated to determine where and how it should be stored. Manufacturers' recommendations should be followed. As a general rule, flammable or combustible liquids, toxic chemicals, explosive chemicals, oxidizing agents, corrosive chemicals, water-sensitive chemicals, and compressed gases should be segregated from each other. They must be stored in such a way that they will not mix with each other if a container leaks or breaks.

It is important to segregate chemicals for storage in a compatible manner.
Two segregation storage systems are provided below:

i. Storage segregation based on WHMIS Hazard Classes

- Sort according to the 6 WHMIS categories described below.
- Prioritize the separation process in the following order:

FLAMMABLE & COMBUSTIBLE MATERIALS
DANGEROUSLY REACTIVE
OXIDIZING MATERIALS
CORROSIVE MATERIALS
COMPRESSED GASES
HIGHLY TOXIC

ii. Segregation for storage based on the BC Fire Code

(BC Fire Code, 2006 - Table 3.2.7.6)

Class	Flammable gases	Non-flammable /non toxic	Toxic/ corrosive gases	Flammable liquids	Flammable solids	Substances subject to spontaneous ignition	Water reactive	Oxidizing substances	Organic Peroxides	Poisonous Substance	Corrosives
Flammable gases	**-**	**P**	**X**	**P**	**P**	**A**	**DS**	**X**	**X**	**X**	**X**
Non-flammable /non toxic	**P**	**-**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**
Toxic/ corrosive gases	**X**	**P**	**-**	**X**	**A**	**A**	**DS**	**A**	**X**	**DS**	**A**
Flammable liquids	**P**	**P**	**X**	**-**	**P**	**A**	**A**	**X**	**X**	**DS**	**A**
Flammable solids	**P**	**P**	**A**	**P**	**-**	**A**	**DS**	**X**	**X**	**DS**	**A**
Substances subject to spontaneous ignition	**A**	**P**	**A**	**A**	**A**	**-**	**DS**	**X**	**X**	**DS**	**A**
Water reactive	**DS**	**P**	**DS**	**A**	**DS**	**DS**	**-**	**X**	**X**	**DS**	**X**
Oxidizing substances	**X**	**P**	**A**	**X**	**X**	**X**		**-**	**X**	**A**	**X**
Organic Peroxides	**X**	**P**	**X**	**X**	**X**	**X**	**X**	**X**	**-**	**X**	**X**
Poisonous Substance	**X**	**P**	**DS**	**DS**	**DS**	**DS**	**DS**	**A**	**X**	**-**	**A**
Corrosives	**X**	**P**	**A**	**A**	**A**	**A**	**A**	**X**	**X**	**A**	**-**

P Permitted; items may be stored together.
X Incompatible items; do not store together in same storage facility.
A Incompatible items; separate by minimum of 1 meter distance.
DS Defer to Material Safety Data Sheet.

6.4 Storage Guidelines of Specific Hazard Classes

i. Compressed Gases

- Protect cylinders from excessive variations in temperature, ignition sources, and direct contact with the ground.
- Label empty cylinders and store them separately from other cylinders.
- Use smallest, returnable size containers and quantities
- Keep all compressed gas cylinders upright and fully secured against falling
    - Individually chain or strap compressed gas cylinders.
    - Store lecture bottles upright and chain, or secure in a proper holder.
- Store in central, properly ventilated area that includes forced ventilation from floor to ceiling and with exhaust above roof level.
- Storage according to compatibility
- If flammable gasses are stored indoors, the room must have a 2-hour fire separation with entry from the exterior. Natural ventilation to outside wall must exist, and the room must have no other purpose.
- Separate flammable gases from oxidizing gases with noncombustible partitions.
- If pressure testing is required, indicate on the cylinder when it was pressure-tested.
- Routily check hazard gases for leaks
- Store hazardous gases with poor warning properties in exhasted enclosures

ii. Flammable Liquids

Flammable liquids should be stored in a dry, cool well-ventilated area, preferably a flammable materials storage cabinet or room.

a) Laboratory Storage

Flammable liquids should be stored:

- Storage cabinets must be conspicuously labeled to indicate that they contain flammable liquids.
- No combustible material is permitted in storage rooms.
- Do not store in or adjacent to exits, elevators, or routes that provide access to exits.
- Consult the 2006 BC Fire Code and your local fire department for specific details.
- If flammable liquids are to be stored cold, the refrigerators and freezers must meet explosion proof standards.
- According to the BC Fire Code the maximum volume of flammable and combustible liquid allowed outside a flammable safety cabinet is 10L including not more than 5L of flammable liquids
- Flammable liquid safety cans of up to 25L can be used for flammable liquid storage out side safety cabinet
- In listed approved metal safety cans which meet the fire code requirements that are equipped with a flash arrestor and self-closing lid.
- In appropriate 5 litre waste solvent containers that are capped when not in active use.

b) Flammable Liquid Cabinets
An approved flammable liquid storage cabinet may be used when quantities of flammables are near or exceed 25 litres. An approved flammable liquid storage cabinet must be listed by an acceptable testing agency and approved by the local Fire Department.

Flammable liquid cabinets provide:
- A safe means of storage over a short period of time.
- A time-saving method of storage by locating cabinets in, or adjacent to work areas which reduces the frequency of trips to the drum storage or dispensing facility.

Flammable liquids cabinets must:
- Be Underwriters Laboratories of Canada (ULC) listed and approved.
- Be closed at all times, with door latches operable.
- Have vents that are either plugged or vented directly to the outside.
- Be either wood (must meet specifications of fire code) or metal.
- Be suitably placed; ie. not located near an exit door or blocking access to an exit route.
- May have to be in a room which has a second exit depending on the quantity and hazards of flammable liquids in the room.
- Contain no more than 500 litres maximum of flammable and combustible liquids of which no more than 250 litres may be flammable.
- Be no more than one (1) per fire compartment, unless approved by the local Fire Department.

c) Flammable Liquid Storage Rooms
A properly designed flammable liquids room must satisfy many requirements, e.g. location, ventilation, electrical equipment. fire protection, etc. It must also meet the needs of the user, e.g. adequate size, conveniently located, etc.

The flammable liquids storage room should be easily accessible to fire fighting; i.e. located in corners of buildings over window openings and doors all providing sufficient entry. Explosion venting can then be incorporated into the exterior walls.

Specific guidelines for flammable liquid storage rooms include the maximum number of litres per square metre of floor space, maximum room size with and without a sprinkler system (or other automatic extinguishing system) and the fire resistance rating of the interior walls.

d) Refrigerator Storage
Refrigerators must be approved (ULC) for storage of flammable liquids (explosion-proof), or acceptably tested and approved. A number of refrigerators have exploded due to flammable vapours.

iii. Toxic Materials

- Store in secured area.
- For carcinogen and reproductive toxins secondary containment is recommended.

iv. Corrosive Acids and Bases

- Store acids and bases separately.
- Store in dedicated corrosive cabinets.
- Store oxidizing acids (eg. nitric acid) away from organic acids (e.g. acetic acid).
- Store hydrofluoric and perchloric acids in secondary containers made from compatible materials.
- Safety showers and eye wash facilities must be within easy access.
- Protective equipment must be inspected regularly to insure proper working order, especially in corrosive atmospheres.

v. Reactive Chemicals

- Store in cool, dry area away from normal work areas and protected from shock, vibration, incompatible chemicals, elevated temperatures, and rapid temperature changes
- Store as required according to the nature of their individual hazards e.g. metal hydrides; some hydrogenation catalysts; picric acid; dinitrophenol; trinitrotoluene
- For air reactive chemicals use a glove box or fill the head space of the container with an inert gas before sealing the container.
- Water sensitive chemicals
    - Store in cool, dry areas designed to prevent accidental contact with water and other incompatible substances.
    - Storage construction should be fire-resistant.
    - Protect chemicals from water from sprinkler systems.
- Secondary containment is recommended.

vi. Oxidizers and Peroxidizable Compounds

Store oxidizers separate from flammable or combustible materials and reducing agents e.g. nitrates; chromates; permanganates; chlorates; peroxides

All peroxidizable compounds should be stored away from heat and light (which catalyse the peroxidation reaction) and reducing agents, and protected from physical damage and ignition sources.

An inventory of all peroxidizable material is required. These substances must be inspected and tested for peroxides regularly after the container is opened. A simple test procedure for detection of peroxides in substances such as alkali metals, alkali metal alkoxides, amides or organometallics is not available.

VII. Chemical Laboratory Emergency Response

7.1 Introduction

Report all incidents, accidents and hazardous conditions to your supervisor and to the Department of Health Safety and Environment as soon as possible after an incident has occurred. Use the Incident/Accident Report Forms to report all fires, injuries, chemical exposures and spills.

All buildings/ departments at UBC must have

- a local safety committee
- a fire and safety plan
- a posted emergency evacuation plan
- an emergency meeting location
- a building emergency director
- floor wardens for each floor or area
- first aid as required by WorkSafeBC

Emergency Procedures must be posted in the workplace at appropriate sites such as next to the elevator, entrances to stairwells and in areas where hazardous materials, equipment or processes are located. Emergency procedures should include response measures for responding to fires, explosions, first aid and life-threatening injuries, and hazardous materials exposures and spills.

7.2 Fire Safety Procedures

Where fire is involved, the procedure is to:

- Activate the fire alarm, alert others, and move everyone away from the area of the fire, closing doors behind you.
- Call 9-1-1 from a safe place.
- Use the stairway, proceeding down to the ground floor, never up. Never use elevators if fire is suspected.
- Use a fire extinguisher only if it is safe, i.e. there is a means of exiting if the fire cannot be controlled; or leave area.
- Use the stairway, proceeding down to the ground floor, never up. Never use elevators if fire is suspected.
- Return to workplace only when authorized by fire warden or fire safety director.
- Once outside, proceed to the predetermined area so that a head count can be taken. Find out the location of your predetermined area *before* a fire occurs

i. General Guidelines for Buildings

Work and storage areas must be kept clean and free of accumulations of combustibles not essential to operations. Access to buildings must be maintained for fire fighters.

A fire safety emergency and evacuation plan and procedures must be developed.
a) The plan will include:

- sounding the alarm
- notifying the fire department
- instructing personnel on procedures to follow
- when alarm sounds, confine/control and extinguish fire if safe, evacuate building.
- scheduling of fire drills and inspections.

b) Fire exit rules include:
- Access to exits and exits must be kept clear.
- Corridors and stairwells must be kept free of obstructions and combustibles.
- Fire doors must not be wedged open.
- Some labs have 2 exits - know their location.

i. Fire Extinguishment

Portable extinguishers must be provided and maintained. Occupants should know:
- Where they are;
- How to use them – consider taking a hands-on fire extinguisher training course from the local fire department;
- Not to block access to them – do not use them for hanging lab coats; and

Contact Facilities Management at 7-9272 for replacement of discharged extinguishers.

Note – small fire extinguishers, about 10 lb (4 kg) in size, last for less than 15 seconds, and have an effective spray for about 7 seconds before the pressure begins to lessen. Keep this in mind when trying to fight a fire with a small extinguisher. If the fire is larger than a garbage can, the fire extinguisher will most likely be unable to control it.

It is important that the appropriate fire extinguisher be used on a particular fire. The table below describes the 4 different types of extinguishers and the types of fires they are meant for.

Class	Type of Fire
A	Ordinary combustibles: wood, cloth, paper, rubber, many plastics
B	Flammable liquids: e.g. gasoline, oil, grease, tar, oil-based paint, lacquer
C	Live electrical equipment
D	Combustible metals

7.3 Treatment of Injuries

In the event of personal injury, the treatment of the injury must take precedence.
Visit the First Aid room in Arts 223 during regular business hours (8:30am-4:00pm, Monday to Friday) or have a First Aid Attendant visit the scene by calling 7-8111. A First Aid Attendant is available 24 hour/day, 365 days/year. This service is provided to the user free-of-charge to all university employees.

- Treat the immediately threatening condition, which may require control of bleeding, CPR or washing of chemical exposed skin for 15 minutes.
- Advise emergency personnel of the chemical name, extent of injuries, hazards of the material and location of victim.

7.4 Spill Clean-Up Procedures

There are various steps that laboratory personnel can take in the event of a laboratory spill. The laboratory worker may be able to respond to a small contained lab spill. Laboratory workers should never put themselves in harms way. If there is any doubt about the safety of the individual in the lab, immediately call 911 or 7-8111.

It is essential to know what chemicals are involved, the quantity of the spill, and the exact location of the spill. The safety of everyone in the laboratory and everyone else in the building is foremost important

In order to place your laboratory in a position to be able to handle a small spill, preplanning is necessary. Laboratories must have a minimum amount of personal protective equipment (PPE) and appropriate clean-up materials present prior to an incident. The minimum PPE needed includes:

a. goggles
b. lab coats
c. rubber booties
d. a spill cart

For All Spills*:*

If appropriate equipment and trained personnel are not available on site, the clean-up should not proceed. Contact Campus Security at 7-8111 for support.

WorkSafeBC Regulations state:

Written safe work procedures must be prepared for hazardous operations, including chemicals, spill response, and workers must be adequately instructed in and follow the procedures. Accidental release or spills of chemicals or other hazardous substances must be controlled immediately, and cleaned up under the supervision of persons knowledgeable in the hazards involved and the precautions to be taken during the cleanup operations. It is the responsibility of the supervisor to ensure personal protective equipment required during emergency cleanup or escape is immediately available.

You should call 807-8111 whenever you:

- Feel unsafe!
- Don't have anyone in the lab to assist you with clean-up
- Don't have appropriate clean-up materials
- Don't have trained personnel available
- Don't have the appropriate PPE available
- Don't know the identity of the chemical
- Have a solvent spill near an ignition source
- Spill more than 1L of a chemical

For detailed information please see the Spill Clean Up Procedure.

- Flammable solvents
- Acids
- Caustics
- Hydrofluoric Acid
- Perchloric Acid
- Mercury

7.5 Safety Showers and Eye Wash Stations

Emergency showers and eye washes should be available to all laboratory personnel who work with large quantities of hazardous materials. Plant Operations personnel are responsible for the annual testing of showers.

Laboratory supervisors are responsible for ensuring that eye washes are flushed weekly to clear them of particulate that could damage eyes during emergency use.

Safety showers provide an effective means of treatment in the event that chemicals are spilled or splashed onto the skin or clothing. Safety shower facilities should be installed wherever corrosive chemicals are used (e.g. acids or alkalis) and must be readily available to all personnel.

Safety showers should be in a clearly marked location. The facility should be no more than 100 feet, or 10 seconds, away from every lab work bench. Laboratory workers should be able to locate the shower(s) with their eyes closed (emergency situations may leave victims temporarily blind).

VIII. Equipment Safety

It is vital that laboratory personnel understand how to correctly and safely use the apparatus that is needed in any given experiment. This includes the use of basic types of glassware, distillation, filtration and low pressure apparatus as well as more expensive and sophisticated instruments such as gas and liquid chromatographs and spectrometers. Laboratory equipment that presents a physical hazard to workers must be adequately safeguarded, shielded, or isolated by location.

Awareness of potential hazards in the use of all types of equipment must be recognized and the appropriate procedures in place. This includes emergency procedures for responding to utility shutdowns and interruptions requiring evacuation. Equipment must be properly maintained in order for it to operate safely and correctly. Broken or chipped glassware or leaking hoses should not be used, especially with low pressure systems.

Written procedures are required wherever the equipment, process or materials used are potentially hazardous.

A log book should be used for all potentially hazardous equipment. Advise co-workers of potential hazards. Post emergency procedures with name and phone number of contact person. Prior to the start of all new projects, tasks, or processes, a hazard assessment should be done.

A project control hazard analysis checklist is provided in Appendix I.

8.1 Refrigerators

When chemicals need to be stored in a refrigerator or freezer, certain guidelines must be followed. The materials must be securely packaged, tightly sealed and properly labeled. The containers for highly reactive materials must be inspected regularly to ensure they are secure, tightly sealed and in good condition. Refrigerators should be frost free to prevent water drainage. **Flammable materials** (flash point < 37.8°C) that require cold storage must be stored in an **explosion proof unit.** All volatile materials must be compatible with the construction materials of their containment.

8.2 Temperature Control

Experimental investigations can be carried out under a variety of temperature conditions.

Although easy to use, heating mantles are not always the best means of applying heat. Hot spots can quickly develop causing sudden boiling and eruption of the contents of the vessel being heated. It is also difficult to know the exact temperature at the surface of the vessel or its contents at any particular time.

When heating flammable solvents to very high temperatures, a hot water, oil or sand bath may be appropriate. A stirred water or oil bath is easily controlled and monitored. Select your heat source based on the characteristic of the chemicals being used, the temperature required, and the procedure being followed.

Heat sources should never be left unattended (e.g. gas burners, hot plates, heating mantles, sand baths, etc.) unless emergency procedures, including a contact name and phone number, are posted adjacent to the apparatus. Automatic shut-off systems for unattended experiments that depend on heat, water, vacuum or power sources are recommended. Before using any heating device:

- in case of overheating, check to see if the unit has an automatic shutoff
- inspect the electrical cords and have them replaced as required;
- make sure the apparatus has been maintained as required by the manufacturer;
- check to see if all heating units in use without automatic shut-off have been turned off before leaving an area for any extended period of time.

Experiments requiring cooling need careful consideration of the process being used. Combinations of solvent and dry ice may be highly flammable. Low temperature coolants, besides being a source of "freezer burns", can condense oxygen creating a potentially explosive atmosphere. Proper personal protective equipment such as a lab coat, face shield and suitable gloves are recommended.

8.3 Control of Suck-Back

Wherever there is a flow of gas or liquid into a system, there is danger of suck-back of those fluids into the original container or system (eg. gas cylinder or domestic water supply). This is easily prevented by the use of one-way valves. Where goose-neck tops are present, it is necessary to install a one-way valve on the tap or plumbing system if a hose from the top into the sink is used.

8.4 Reduced Pressure Operations

Glass vacuum containers, such as desiccators and flasks, should be wrapped with tape to prevent glass from flying in the event of an implosion or explosion.

When carrying out filtration or distillation procedures under reduced pressure, the heavy-walled glassware and tubing must be undamaged and able to withstand the conditions of reduced pressure. Cold traps should be used to prevent leaking of vapours from the experiment to the oil of the vacuum pump or the water passing through a water aspirator.

Rotoary evaporation of solvents using a water aspirator is not appropriate where the vapour being removed is highly odorous or toxic unless a suitable cold trap is available to capture them. Alternative enclosed systems are recommended.

8.5 Centrifuge Safety

Potential hazards are associated with centrifuges include physical hazards from moving parts or mechanical failure and chemical hazards from contact with spilled material.

Do not attempt to operate a centrifuge until you have received instruction in its specific operation. Read the operation manual, if available, and ask an experienced colleague or supervisor to demonstrate procedures.

Ensure tabletop centrifuges are securely anchored to a location where its vibration will not cause bottles or equipment to fall. Other rules for safe operation of centrifuges are:

- Lid must be closed during operation.
- Opposite sockets must be balanced with an equal weight of material (in the same type of tube for simplicity).
- Centrifuge must be monitored until full operating speed is attained and the machine is running safely without vibration.
- If vibration occurs, stop centrifuge immediately and check load balances; check swing-out buckets for clearance and support.
- Tubes must be sealed to prevent the exposure of biohazards, carcinogens, radioactive materials, solvents, corrosives, etc. to the centrifuge itself.
- Do not open the centrifuge lid until the centrifuge has stopped moving completely.
- Discard plastic centrifuge tubes after one cycle of ultra-centrifugation (high failure rate).
- Use nitrocellulose tubes only when transparent and flexible (fresh); they must never be heated because of explosive possibility.
- Rotors and buckets must be regularly cleaned with non-corrosive cleaning solutions.
- Record of all uses and maintenance activities must be kept.

As per WorksafeBC Regulations Part 30:

Unless exempted by *CSA Standard C22.2 No. 151-M1986 Laboratory Equipment,* or other standard acceptable to the Board, centrifuge doors must be interlocked to prevent workers accessing spinning rotors**.** The interlock must prevent the door from opening while the rotor is spinning or because the rotor to brake if the door is opened or another equally effective means must be used to prevent a worker from accessing the spinning rotor.

8.6 Electrophoresis apparatus

Electrophoresis is a separation technique that involves the migration of charged molecules through fluid medium under the influence of an electrical field. The apparatus must be designed and maintained so that electrical current is shut off when the cover is opened. A label must warn workers of the electrical hazard. Always follow the manufacturer's operational instructions and safety guidelines.

IX. Safe Experiment Design

9.1 Introduction

A comprehensive experimental design process is an essential step in running safe laboratory operation. This process should review the potential hazards associated with each experiment over its life cycle. It is instrumental in maintaining safe laboratory operations, minimizing exposure to potential hazards, minimizing waste generation and ensuring regulatory compliance.

In this process, the whole range of experimental steps should be considered. From the development of clear experiment goals and objectives, through acquisition, setup and handling of materials and equipment, detailed assessment of chemicals and reactions, all the way to storage and disposal practices, each step should be examined to determine safety issues and environmental concerns.

Detailed information related to potential hazards identified and safety measures to be implemented should be incorporated to the experimental protocol and be an integral part of it! A guide on hazard control analysis is provided in Appendix F.

9.2 Responsibility

Principal Investigators and supervisors are responsible for ensuring that effective pre-experiment review is implemented for each laboratory protocol prepared by a lab worker.

Reference: Work Safe BC OSH Regulation 30.14 Laboratory Procedures

9.3 Procedure

1. State the goals and objectives of your experiment

2. Consider and state all the fundamental steps of the experiment

3. Perform hazard assessment for each step of the experiment or process. Consider the following elements:

i) Hazard evaluation of materials and chemicals to be used:
Complete hazard assessment for all materials and products associated with experiment. If risks are determined to be unacceptable, redesign the experiment, minimize quantities, reduce concentrations, reduce volume or use less hazardous chemical alternatives. Consider the chemical amount, volume, flow rate, physical properties, and the potential for exposure. Address emergency response for unexpected events. Special attention should be given to new materials produced whose physical properties and toxicity are unknown.

ii) Management of chemicals and equipment:
Include provisions for acquiring and storing chemical reagents and equipment, proper equipment set up, handling and operation, inventory management, source reduction, material sharing, monitoring of reactive chemicals, compound shelf life, and storage incompatibility. Consider the potential impact of loss of air, water or power, on your experiment. Assess additional equipment hazard (noise, radiation, electrical hazard, ergonomics).

iii) Working with chemicals:
Include steps such as sample preparation, equipment assembly and commissioning, equipment startup and calibration, product isolation and characterization, storage and disposal of materials after work is completed. Special consideration should be given to planning unattended operations, introduction of new equipment, and significant process scale up.

iv) Types of reactions:
Know the chemistry of your reactions. Be prepared for exothermic reactions, runaway reactions, bumping, pressure build up, generation of hazardous gases or interaction between incompatible materials. Know the physical conditions required for the reaction (e.g. high pressure, vacuum, extremely cold temperature, high temperature, high voltage) and conditions that may develop over the course of the reaction. Consider the potential associated hazards.

v) Equipment, area cleaning and decontamination:
Develop a procedure for equipment and area decontamination. Make sure you are using the proper decontamination procedures and cleaning materials and know how to properly dispose of any residue or waste. Special caution should be taken with reactive materials (air/moisture/water reactive) and when cleaning with solvents. Review compatibility information of cleaning and decontamination agents.

vi) Proper disposal and deactivation procedures:
Consider waste minimization and recycling of materials. Evaluate the properties of all waste products to be generated by the experiment and develop written disposal instructions for each waste stream. Consider the amount and frequency of waste generated and methods to neutralize the waste or render it non-hazardous. Have a procedure in place to deal with unstable waste or wastes that require special storage and handling. Review the compatibility of materials being accumulated. Minimize the generation of multi-hazard waste. Minimize the release of hazardous chemicals to the environment. Do not use the fume hood to dispose of volatile hazardous materials (use filters, scrubbers or other control equipment). Do not discharge hazardous chemicals into the sewer system.

vii) Provide a contingency plan to deal with the unexpected:
Be prepared for emergencies. Include information regarding emergency response in each procedure:

- the location and type of spill control equipment and materials
- the location and type of fire extinguisher required (D type for combustible metals)
- the type and location of antidotes to special hazardous chemicals (HF, cyanide)

viii) Laboratory facilities:
Assess the area proposed for the experiment. Identify any potential hazards. Consider the location of equipment relative to the location of emergency response facilities. Work with hazardous materials should be carried out in the fume hood, glove box or biosafety cabinets. Special needs for bench space, ventilation or shielding may affect experimental planning and should be stated.

ix) Personal protective equipment (PPE) and industrial hygiene monitoring:
Review the need for PPE and determine the type of PPE required for each step of the experiment. Incorporate this information to your protocol. Work with certain materials may require industrial hygiene monitoring or a special occupational health review.

9.4 Sources of Information

Laboratory Pollution Prevention and Waste Management Manual

MSDSs of related materials

X. Laboratory Inspections

At the University of British Columbia, various individuals, groups, and regulatory agencies conduct inspections. Periodically WorkSafeBC carries out unannounced inspections. Kelowna Fire Department also conduct annual inspections of fire extinguishers and other fire-safety issues such as storage of flammable liquids and condition of fire exits.

Under WorkSafeBC Regulation, employers and workers have the right to have a representative accompany the WorkSafeBC officer during regular WorksafeBC inspections. The worker representative should be selected from the Joint Health and Safety Committee.

WorksafeBC Regulation 3.5 General requirement states**:**
Every employer must ensure that regular inspections are made of all workplaces, including buildings, equipment, work methods and practices, at intervals that will prevent the development of unsafe working conditions.

Any deficiencies found during regular inspection by committee members should be reported immediately to the supervisor. If corrective action is not taken to the satisfaction of the committee, the item should be included on the agenda for consideration at the next meeting.

Health Safety and Environment periodically conducts consolidated inspections. These inspections include:

- reviewing training records
- ensuring first aid/fire procedures are posted
- reviewing safe work procedures
- inspecting storage and handling of chemicals
- inspecting equipment safety
- observing use of PPE
- and inspecting safety controls in place

In addition, there are four types of inspections that are required to be conducted by UBC personnel. They are:

- Daily (conducted by each individual, employee or student, of their own work area, to identify and correct hazardous conditions or report them to their supervisor).
- Monthly (conducted by area supervisors or their designate to identify hazardous conditions, using an abbreviated checklist that is posted at the work site).
- Annually (formal laboratory inspections that are the responsibility of the local safety committee; detailed checklist and report to supervisor with appropriate follow-up).
- Special (equipment; post-incident; post-repair; etc.)

Supervisors and workers are responsible for;

- participating in workplace inspections when requested
- making suggestions for corrective actions to those conducting workplace
- inspections
- taking part in training or the development of safe work practices
- developing procedures required as the result of the workplace inspection.

Monthly formal laboratory inspections are the responsibility of local safety committees. The frequency of inspections will vary depending on the size of department, the extent of the potential hazards in the department and the ability of the committee to carry out the inspections.

Larger inspection teams should include both worker and management representatives. The team should be familiar with the work process and, whenever possible, include members of the joint committee or the worker health and safety representative

An example of a chemical laboratory inspection checklist can be found in Appendix J.

XI. Transportation and Receiving of Hazardous Materials on Campus

Transportation of Dangerous Goods

The transport of dangerous goods (i.e. hazardous materials with acute hazards) from any UBC site to another location off-campus is regulated by the Transportation of Dangerous Goods (TDG) Act. Persons who ship, carry or receive such goods must have current certification of training.

Contact Health Safety and Environment for information on the Transportation of Dangerous Goods (TDG).

Receiving Dangerous Goods

Receivers must be trained to examine packages, check documentation and respond to emergencies such as spills. This is to ensure that materials are received in safe, intact containers and accompanying hazard information and documentation is complete.

Contact Health Safety and Environment for information on the TDG Receivers certification.

11.1 Certification

TDG legislation provides that an employer representative must provide a signed certificate for anyone receiving dangerous goods. The certificate is valid for three years and must be available upon the request of an inspector.

11.2 Receiving Procedures

Receiving dangerous goods (DG) involves the following steps:

1. Each package containing DG must be examined to ensure the packaging is intact and the DG have not leaked or spilled from the container.
2. Each package should have the appropriate safety symbols and labels attached.
3. The labels and shipping documents should match. Any errors on classification should be corrected.
4. The package must be stored safely until used.
5. File shipping documents for a minimum of two years.
6. Respond to and report any dangerous occurrences.

11.3 Dangerous Goods Hazard Categories

There are nine hazards classes recognized under TDG. The following table lists the classes and their hazard symbols.

Anyone receiving goods classified as explosive must contact Health Safety and Environment prior to bringing goods on campus.

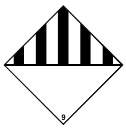
Anyone receiving a good classified as a radioisotope must obtain certification through the UBC Radiation Safety Program. Contact Health Safety and Environment for certification training.

11.4 Shipping Description

Each package must display the following information:

1. The name of the material in the package. For example "hydrochloric acid"
2. The TDG hazard class name and subsidiary classes. For example "Class 8 corrosive"
3. A four-digit material identification number. For example, "UN 1789" is the number for hydrochloric acid.
4. The packing group designation; I, II, III
5. Special handling information such as "Keep from freezing" or "Keep upright"

TDG Class	*Label Symbol*	*Comments*
Explosives [1]		Anyone receiving explosives must consult with Risk Management Services
Compressed Gasses [2]	 	Flammable gases include propane or hydrogen Toxic gases include hydrogen sulphide or chlorine
Flammable Liquids [3]		Flammable liquides have flash points below 61°C.
Flammable Solid [4]	 	These symbols are required on large quantities.
Oxidizers [5]		Examples include nitric acid, and osnium tetroxide
Toxic/infectious [6]		These materials are acutely toxic causing immediate health risk. Example sodium cyanide
Radioactive [7]		Question on the safe handleing of radioisotopes must be reffered to the Risk Management Services Radiation Safety Program
Corrosive [8]		Examples include acids and caustic materials

Miscellaneous [9]		Includes mixed loads, and dangerous waste materials.

11.5 Safety Symbols and Labels

Each package must display the appropriate safety symbols. Examples are provided in the above table.

Symbols and labels may not be removed until the goods are removed from the packaging. Empty containers must have labels defaced or removed, or the boxes flattened. The symbols are to be placed on the packages in a diamond orientation with the corner of the labels pointing upwards. Reduced size labels may be used on compressed gas cylinders and are often located on a reinforced tag attached to the neck of the cylinder.

11.6 Documentation Required

All dangerous goods shipments must be accompanied by TDG shipping papers and must be retained by the receiver for at least two years. TDG shipping papers may be combined with commercial documents such as a Bill of Lading for convenience.

A receiver is responsible for ensuring that information on the document matches the safety marks and label information on the packages. A diligent receiver may also object to poorly prepare shipping papers.

11.7 Handling and Transporting

Transportation of dangerous goods, loading, unloading, or storage should be in away that could not cause the discharge, emission or escape of the dangerous goods from the means of containment that could constitute a danger to health, life property or the environment.

Handlers and transporters must follow any special instructions relating to safe handling and storage, e.g. "Refrigeration required; keep away from heat and flames."

Received materials must be segregated by hazard classes in accordance with the University's chemical storage guidelines (see Section VI of this manual).

11.8 Dangerous Occurrences

If any of the following incidents occur:
1. Any transportation accident involving infectious or radioactive substance;
2. Any unintentional explosion or fire involving dangerous goods; or
3. A spill of a dangerous goods

Contact Campus Security immediately at (250)807-8111. Following the incident, provide a report to Health Safety and Environment.

For more information please see Incident/Accident Report Form, Environmental Reporting Procedures, and Spill Clean Up Procedure.

11.9 Packaging Damaged in Transport

Damaged gas cylinders can be extremely dangerous if rapid release occurs. Leaking cylinders must be returned and may be handled and transported in a road vehicle. Keep the cylinder in a safe (outdoor) location. Contact the supplier immediately to arrange for its return.

Damaged packages containing solid materials of hazard classes 4, 5, 6.1, 8, or 9 may be handled and transported in a road vehicle provided the damage package is repaired. Packages will be marked with the words "FOR SALVAGE" and are transported directly to the consignee or to a point for repackaging or disposal.

Damaged packages containing liquid materials of hazard classes 3, 5, 6.1, 8 or 9 may be handled and transported in a road vehicle provided the damaged package is placed in a steel or plastic drum over-pack.

XII. References

UBC Laboratory Chemical Safety Manual 2002

WorkSafe BC Occupational Health and Safety Regulations:
- Part 5- Chemical Agents and Biological Agents
- Part 6- Substance Specific Requirements
    - Cytotoxic Drugs 6.42-6.58
    - Pesticides application
- Part 7- Noise, Vibration, Radiation and Temperature
- Part 8- Personal Protective Clothing and Equipment
- Part 30- Laboratories

Canadian Centre for Occupational Health and Safety (CCOHS)

WorkSafe BC Laboratory Safety Hand Book

WorkSafe BC WHMIS Instructor's Manual

Transport Canada TDG Regulations

BC Fire Code 2006
- Part 3- Indoor and Out Door Storage
- Part 4- Flammable and Combustible Liquids

Prudent Practices in the Laboratory: Handling and Disposal of Chemicals (1995), National Research Council.

IARC Classifications of Carcinogenic Agents

NTP 11th Report on Carcinogens

APPENDICES

Appendix A: Flash Points of Common Flammable Liquids

The following are Class 1A flammable liquids (flash point < 22.8°C; boiling point < 37.8°C). Closed cup values are given :

Class 1A:

Flammable Liquid	Flash Point (°C)
Ethyl chloride	-50
Pentane	-49
Ethyl ether	-45
Acetaldehyde	-38
Isopropylamine	-37
Ethyl formate	-19
Ethylamine	-18
2-pentanone	7
Methyl methacrylate	10
Methanol	11
Isopropanol	12
Dioxane	12
Ethylene dichloride	13
Octane	13
Propanol	15
Sec-butyl acetate	17
Pyridine	20
Allyl alcohol	21

The following are Class 1B flammable liquids (flash point < 22.8°C; boiling point > 37.8°C), and Class 1C flammable liquids (22.8°C < flash point < 37.8°C):

Class 1B and 1C:

Flammable Liquid	Flash Point (°C)
Allyl chloride	-31
Carbon disulfide	-30
Isopropyl ether	-28
Acrolein	-26
Hexane	-21
Cyclohexane	-20
Ethyl bromide	-20
Nickel carbonyl	-20
Acetone	-17
Naphtha	-18
1,1-dimethylhydrazine	-15
Tetrahydrofuran	-14
Butylamine	-12

Flammable Liquid	Flash Point (˚C)
Benzene	-11
Methyl acetate	-10
Methyl ethyl ketone	-6
Ethyl acetate	-4
Heptane	-4
Acrylonitrile	-1
Methyl isobutyl ketone	22.5
2-butanol	24
n-Amyl acetate	25
2-hexanone	25
Isoamyl acetate	25
Xylene	25
Butyl alcohol	29
Chlorobenzene	29
p-anisidine	30
Sec-amyl acetate	31
Styrene	32
Ethylenediamine	33.5
Morpholine	35
Turpentine	35

Flash point values were taken from *NIOSH Pocket Guide to Chemical Hazards, NIOSH Publication Number 2005-149*

Appendix B: Carcinogens, Reproductive Toxins and Sensitizers

The following is a list of confirmed or suspected carcinogens, reproductive toxins and sensitizers.

IARC- International Agency for Research on Cancer
Group 1: carcinogenic to humans
Group 2A: probably carcinogenic to humans

ACGIH- American Conference of Governmental Industrial Hygienists
Group A1: confirmed human carcinogen
Group A2: suspected human carcinogen

R: confirmed reproductive toxin
S: confirmed sensitizer

NTP- National Toxicology Program
KC: Known to be Human Carcinogen
RAC: Reasonably Anticipated Human Carcinogen

Acrylamide, Inhalable [79-06-1] Revised 2005	2A, RAC
Acrylic acid [79-10-7]	R
Adriamycin (Doxorubicin hydrochloride) [23214-92-8]	RAC
Aflatoxins [1402-68-2]	KC
Allyl glycidyl ether [106-92-3]	S
4-Aminodiphenyl [92-67-1]	A1, 1, KC
Amitrole [61-82-5]	R
tert-Amyl methyl ether (TAME) [994-05-8]	R
Arsenic and inorganic compounds, as As [7440-38-2]	A1, 1,KC
Asbestos - All forms [1332-21-4]	A1, 1, KC
Azinphos-methyl, Inhalable [86-50-0]	S
Benomyl [17804-35-2]	R, S
Benz[a]anthracene [56-55-3]	A2, 2A
Benzene [71-43-2]	A1, 1,KC
Benzidine [92-87-5]	A1, 1, KC
Benzidine based dyes	2A, KC
Benzo[b]fluoranthene [205-99-2]	A2, 2B

Benzo[a]pyrene [50-32-8]	A2, 2A
Benzotrichloride [98-07-7]	A2, 2A, RAC
Benzoyl chloride [98-88-4]	2A
Benzyl chloride [100-44-7]	2A
Beryllium and compounds, as Be [7440-41-7]	A1, 1, KC
Borate compounds, Inorganic, Inhalable [1303-96-4;1330-43-4; 10043-35-3; 12179-04-3] Revised 2005	R
Bromodichloromethane [75-27-4]	RAC
1-Bromopropane [106-94-5] Revised 2005	R
1,3-Butadiene [106-99-0]	A2, 2A, KC
n-Butyl acrylate [141-32-2]	S
n-Butyl glycidyl ether (BGE) [2426-08-6] Revised 2005	R,S
n-Butyl mercaptan [109-79-5]	R
Cadmium and compounds, as Cd [7440-43-9]	A2, 1
Cadmium and compounds, Respirable, as Cd [7440-43-9]	A2, 1, KC
Calcium arsenate, as As [7778-44-1]	A1, 1
Calcium chromate, as Cr [13765-19-0]	A2, 1
Captafol [2425-06-1]	2A,S
Captan, Inhalable [133-06-2]	S
Carbaryl [63-25-2]	R
Carbon monoxide [630-08-0]	R
Carbon tetrachloride [56-23-5]	A2, 2B, RAC
2-Chloroacetophenone [532-27-4]	S
Chlorambucil [305-03-3]	KC
Chlorodiphenyl (42% chloride) [53469-21-9]	2A
1-(2-Chloroethyl)-3-(4-Methylcyclohexyl)-1-Nitrosourea [13909-09-6]	KC
Chloroform [67-66-3]	R
bis(Chloromethyl) ether [542-88-1]	A1, 1, KC
Chloromethyl methyl ether [107-30-2]	A2, 1

beta-Chloroprene [126-99-8]	R
2-Chloropropionic acid [598-78-7]	R
4-Chloro-o-Toluidine [95-69-2]	2A
Chromite ore processing (Chromate), as Cr A1 Chromium (VI) inorganic compounds - Insoluble, as Cr [7440-47-3]	A1, 1
Chromium (VI) inorganic compounds - Water soluble, as Cr [7440-47-3]	A1, 1, KC
Coal tar pitch volatiles, as benzene-soluble aerosol [65996-93-2]	A1, 1, KC
Coke Oven Emissions	KC
Cyclophosphamide [50-18-0]	KC
Cyclosporin A [59865-13-3]	KC
Demeton-S-methyl, Inhalable [919-86-8]	S
Diazomethane [334-88-3]	A2
Dibutyl phthalate [84-74-2]	R
Dichloroacetic acid [79-43-6] Revised 2005	R
1,4-Dichloro-2-butene [764-41-0]	A2
2,2-Dichlorodiethyl sulfide (Mustard Gas) [505-60-2]	1
2,2'-Dichloro-n-methyldiethylamine (Nitrogen mustard) [51-75-2]	2A
Dichlorvos (DDVP), Inhalable [62-73-7]	S
Diethylstilbestrol [56-53-1]	KC
Diethylene triamine [111-40-0]	S
Diethyl sulfate [64-67-5]	2A, RAC
Diglycidyl ether (DGE) [2238-07-5]	R
N,N-Dimethylacetamide [127-19-5]	R
Dimethyl carbamoyl chloride [79-44-7]	A2, 2A, RAC
1,2-Dimethylhydrazine [540-73-8]	2A
Dimethyl sulfate [77-78-1]	2A, RAC
Dinitrotoluene [25321-14-6]	R
1,3-Dioxolane [646-06-0]	R

Dodecyl mercaptan [112-55-0] Revised 2004	S
Epichlorohydrin [106-89-8]	2A, R
Erionite {66733-21-9]	KC
2-Ethoxyethanol (EGEE) [110-80-5]	R
2-Ethoxyethyl acetate (EGEEA) [111-15-9]	R
Ethyl tert-butyl ether (ETBE) [637-92-3]	R
Ethylenediamine [107-15-3]	S
Ethylene dibromide [106-93-4]	2A, RAC
Ethylene oxide [75-21-8]	A2, 1, KC, R
2-Ethylhexanoic acid, Inhalable [149-57-5]	R
Flour dust, Inhalable	S
Formaldehyde [50-00-0]	A2, 1, S
Gallium arsenide, Respirable [1303-00-0] Revised 2005	1
Glutaraldehyde, Activated & inactivated [111-30-8]	S
Glycidol [556-52-5]	2A
Glyoxal, Inhalable [107-22-2]	S
Hexafluoroacetone [684-16-2]	R
Hexahydrophthalic anhydride, all isomers, Inhalable [85-42-7; 13149-00-3; 14166-21-3] Revised 2004	S
Hexamethylene diisocyanate (HDI) [822-06-0]	S
1-Hexene [592-41-6]	R
2-Hydroxypropyl acrylate [999-61-1]	S
Isophorone diisocyanate [4098-71-9]	S
Lead - elemental and inorganic compounds, as Pb [7439-92-1] Elemental	2B;R/Other inorganic 2A, R, RAC
Lead arsenate, as Pb3(AsO4)2 [3687-31-8]	2A; R
Lead chromate, as Cr [7758-97-6]	A2, 2A; R
Lead chromate, as Pb [7758-97-6]	A2, 2A; R
Maleic anhydride [108-31-6]	S
Manganese - Elemental & inorganic compounds, as Mn [7439-96-5]	R
Melphalan [148-82-3]	KC

Mercury - Elemental, as Hg [7439-97-6]	R
Mercury - Inorganic compounds, as Hg [7439-97-6]	R
2-Methoxyethanol (EGME) [109-86-4]	R
2-Methoxyethyl acetate (EGMEA) [110-49-6]	R
Methyl acrylate [96-33-3]	S
Methyl tert-butyl ether (MTBE) [1634-04-4]	R
Methyl chloride [74-87-3]	R
Methyl isocyanate [624-83-9]	S
Methyl methacrylate [80-62-6]	S
Methyl vinyl ketone [78-94-4]	S
4,4'-Methylene bis(2-chloroaniline) (MBOCA; MOCA) [101-14-4]	A2, 2A
Methylene bisphenyl isocyanate (MDI) [101-68-8]	S
Naled, Inhalable [300-76-5]	S
beta-Naphthylamine [91-59-8]	A1, 1. KC
Natural rubber latex, as Total proteins, Inhalable [9006-04-6] Revised 2004	S
Nickel - Insoluble inorganic compounds, as Ni [7440-02-0]	A1, 1, RAC
Nickel - Elemental, Soluble inorganic compounds, as Ni [7440-02-0]	A1, 1, RAC
Nickel subsulfide, as Ni, Inhalable [12035-72-2]	A1, 1
4-Nitrodiphenyl [92-93-3]	A2
n-Nitrosodiethylamine [55-18-5]	2A, RAC
n-Nitrosodimethylamine [62-75-9]	2A, RAC
Nitrous oxide [10024-97-2]	R
Oil mist - mineral, mildly refined	1
p-Phenylenediamine [106-50-3]	S
Phenyl glycidyl ether (PGE) [122-60-1]	R, S
Phenylphosphine [638-21-1]	R
Phthalic anhydride [85-44-9]	S
Picric acid [88-89-1]	S

Piperazine and its Salts, as Piperazine [110-85-0]	S
Platinum - Soluble salts (as Pt) [7440-06-4]	S
Propylene oxide [75-56-9]	S
Pyrethrum [8003-34-7]	S
Rosin core solder thermal decomposition products (colophony) [8050-09-7]	S
Silica, Crystalline - Cristobalite, Respirable [14464-46-1]	1, KC
Silica, Crystalline - Quartz, Respirable [14808-60-7]	A2, 1, KC
Silicon carbide, Fibrous (including whiskers) [409-21-2] Revised 2003	A2
Strontium chromate, as Cr [7789-06-2]	A2
Subtilisins, as crystalline active enzyme [1395-21-7; 9014-01-1]	S
Sulfuric acid, Thoracic [7664-93-9] Revised 2004	A2, 1, KC
Synthetic Vitreous Fibres - Refractory ceramic fibres	A2, 2B
Talc - Containing asbestos fibres [14807-96-6]	A1, 1
Tamoxifen [10540-29-1]	KC
2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD); "Dioxin" [1746-01-6]	KC
Tetrachloroethylene (Perchloroethylene) [127-18-4]	2A, RAC
Tetrakis (hydroxymethyl) phosphonium sulfate [55566-30-8] Revised 2005	S
Tetryl [479-45-8]	S
Thiotepa [52-24-4]	KC
Toluene-2,4-diisocyanate (2,4-TDI) [584-84-9]	S, RAC
Toluene-2,6-diisocyanate (2,6-TDI) [91-08-7]	S, RAC
o-Toluidine [95-53-4]	2A, RAC
Trichloroethylene [79-01-6]	2A, RAC
1,2,3-Trichloropropane [96-18-4]	2A, RAC
1,3,5-Triglycidyl-s-triazinetrione [2451-62-9]	R;S
Trimellitic anhydride [552-30-7]	S

Turpentine [8006-64-2] and selected monoterpenes [80-56-8; 127-91-3; 13466-78-9] Revised 2003	S
Uranium (Natural) - Insoluble compounds, as U[7440-61-1]	A1, 1
Uranium (Natural) - Soluble compounds, as U [7440-61-1]	A1
Vinyl bromide [593-60-2]	A2, 2A, RAC
Vinyl chloride [75-01-4]	A1, 1, KC
4-Vinyl cyclohexene [100-40-3]	R
Vinyl cyclohexene dioxide [106-87-6]	R
Vinyl fluoride [75-02-5]	A2, 2A, RAC
Wood dust - Allergenic species	1, KC
Wood dust - Non-Allergenic Hardwood	A1, 1, KC
Wood dust - Non-Allergenic Softwood	1, KC
Zinc chromates, as Cr [13530-65-9; 11103-86-9; 37300-23-5]	A1

Appendix C: Dangerously Reactive Materials (from TDG List)

Self reactive substances and solid desensitized explosives

2-Bromo-2-nitropropane-1,3-diol
2-Amino-4,6-dinitrophenol (>20%water)
5-tert- Butyl-2,4,6-trinitro-m-xylene
Aluminum powder
Aluminum resinate
Ammonium picrate (dry or w less than 10% water)
Azodicarbonamide
Barium azide (dry or wetted with less than 50% water)
Borneol
Calcium resinate
Cobalt naphthenates powder
Cobalt resinate
Decaborane
Dicyclohexylammonium nitrate
Dinitrophenolates (w more than 15% water)
Dinitroresorcinol (w more than 15% water)
Dipicrylsulfide (w more than 10% water)
Dipicrylsulphide (w more than 10% water)
Ferrocerium (unstabilized against corrosion or w less than 10% iron)
Hexamethylenetetramine
Isosorbide-5-mononitrate
Lead phosphate dibasic
Magnesium alloys (>50% magnesium)
Manganese resinate
Molten sulfur
Naphthalene
Nitrocellulose w alcohol (alcohol>25%, nitrogen<12.65%)
Nitrocellulose w water (water >25%)
Nitroguanidine (water>20%)
Nitronaphthalene
Nitrostarch (water>20%)
Paraformaldehyde
Phosphorus, amorphous
Phosphorus heptasulfide
Phosphorus sesquisulfide (free from yellow and white phosphorus)
Phosphorus trisulfide (free from yellow and white phosphorus)
Picrite (water>20%)
Silicon powder, amorphous

Silver picrate (water>30%)
Sodium dinitro-o-cresolate (15%<water)
Sodium picramate (20% >water)
Sulfur
Titanium hydride
Titanium powder wetted(25%<water)
Trinitrophenol (30%<water)
Trinitrotoluene (30%<water)
Urea nitrate (water <20%)
Zinc resinate
Zirconium hydride
Zirconium picramate (20%<water)
Zirconium powder (25%<water)

Materials liable to spontaneous combustion

Aluminum borohydride
Barium alloys, pyrophoric
Calcium alloys, pyrophoric
Calcium hydrosulfite
Calcium, pyrophoric
Carbon activated
Copra
Cyclooctadiene phosphine
Hafnium powder
Iron oxide
Lithium alkyls
Magnesium alkyls
Magnesium diamide
Magnesium diphenyl
Maneb
Pentaborane
Phosphorus, white (dry, solution, molten)
Phosphorus, yellow (dry, solution, under water)
p-Nitrosodimethylaniline
Potassium hydrosulfite
Potassium sulfide (30%> water)
Potassium sulfide, anhydrous
Sodium dithionite
Sodium hydrosulfide (water<25%)
Sodium hydrosulfite

Sodium methylate
Sodium sulfide (water<30%)
Sodium sulfide anhydrous
Thiourea dioxide
Titanium trichloride, pyrophoric
Titanium disulfide
Titanium powder dry
Xanthates
Zirconium powder dry

Substances that release flammable gases in contact with water

Aluminum carbide
Aluminum ferrosilicon powder
Aluminum hydride
Aluminum phosphide
Aluminum silicon powder
Barium
Boron trifluoride dimethyl etherate
Caesium
Calcium
Calcium carbide
Calcium cyanamide (w > 0.1 calcium carbide)
Calcium hydride
Calcium phosphide
Calcium silicide
Cerium
Chlorosilanes
Ferrosilicon (90%>silicon>30%)
Lithium
Lithium aluminum hydride
Lithium borohydride
Lithium ferrosilicon
Lithium hydride
Lithium nitride
Lithium silicon
Magnesium alloys powder
Magnesium aluminum phosphide
Magnesium hydride
Magnesium phosphide
Magnesium powder

Magnesium silicide
Methyldichlorosilane
Phosphorus pentasulfide (free from yellow and white phosphorus)
Potassium
Potassium borohydride
Potassium metal alloys
Potassium phosphide
Potassium sodium alloys
Rubidium
Sodium
Sodium aluminum hydride
Sodium borohydride
Sodium hydride
Trichlorosilane
Zinc dust
Zinc phosphide
Zinc powder

Appendix D: Explosives and Potentially Explosive Chemical Lists

Explosive and Potentially Explosive Chemical Families

Acetylene or acetylide compounds:
N-Chloro-3-aminopropyne
Propiolic acid
Propynethiol
Acyl azides
Acetyl azide
Cyanodiazoacetyl azide
Phenylphosphonic azide chloride
Acyl hypohalites
Acetyl hypobromite
Hexafluoroglutaryl dihypochlorite
Alkyl nitrates
Ethylidene dinitrate
Glyceryl trinitrate
Propyl nitrate
Alkyl perchlorates
Hexyl perchlorate
Ethyl perchlorate
1-Chloro-2-propyl perchlorate
Allyl trifluoromethanesulfonates
2-Chloro-2-propenyl trifluoromethanesulfonate
Amminemetal oxosalts
Ammonium hexanitrocobaltate
Bis(1,2-diaminoethane) diaquacobalt (III) perchlorate
Trihydrazine nickel (II) nitrate
Aromatic nitrates
Picric acid
Trinitrobenzene
Picryl sulfonic acid
Azides
Sodium azide
Lead azide
Hydrogen azide
Aziridines
1-Bromoaziridine

Azocarbaboranes
1,1-`Azo-1,2-dicarbadecaborane
N-Azolium nitroimidates
Benzimidazolium 1-nitroimidate
4-Nitroamino-1,2,4-triazole
2-(N-Nitroamino)pyridine N-oxide
Diazo compounds
2-Buten-1-yl diazoacetate
Diethyl diazomalonate
Dinitrodiazomethane
Diazonium carboxylates, perchlorates, salts, sulfates, tetrahaloborates, and, triiodides
Benzenediazonium-2-carboxylate
4-Aminobenzenediazonium perchlorate
6-chloro-2,4-dinitrobenzenediazonium sulfate
2-Nitrobenzenediazonium tetrachloroborate
4-Toluenediazonium triiodide
Difluoroaminoalkanols
1,1-Difluorourea
Perfluoro-N-cyanodiaminomethane
Fluoro–nitro compounds
1-Fluoro-1,1-dinitrobutane
Fluorodinitromethyl azide
Fulminating metals
Lead fulminate
Gold fulminate
Silver fulminate
Furazan N-oxides
Dicyanofurazan N-oxide
4-Oximino4,5,6,7-tetrahydrobenzofurazn N-oxide
Hydroxooxodiperoxochromate salts
1-Ammonium hydroxooxodiperoxochromate
Potassium hyroxooxodiperoxochromate
Iodine Compounds
Calcium 2-iodylbenzoate

Iodobenzene
2-Iodylvinyl chloride
Isoxazoles
3-Aminoisoxazole
3,5-Dimethylisoxazole
Metal Azide Halides
Chromyl azide chloride
Molybdenum diazide tetrachloride
Tungsten azide pentachloride
Metal Azides
Aluminum azide
Bis(cyclopentadienyl)tungsten diazide oxide
Mercury (I&II) azide
Sodium azide
N-Metal Derivatives
Cadmium nitride
Dibutylthallium isocyanate
Sodium amide
Metal Fulminates
Mercury (II) fulminate
Sodium fulminate
Tripropyllead fulmintate
Metal Halogentates
Lead bromate
Metal Hydrides
Stibine (Antimony hydride)
Metal Nitrophenoxides
Lithium 4-nitrothiophenoxide
Potassium 4-nitrophenoxide
Metal Oxides
Bis (1-chloroethylthallium chloride) oxide
Magnesium chloride trioxide
Metal Oxohalogenates
Ammonium iodate
Lead acetate—lead bromate
Metal Oxometallates

Bis (benzene) chromium dichromate
Metal Perchlorates
Chromyl perchlorate
Metal Peroxides
Many transition metal peroxides are dangerously explosive.
Metal Peroxomolybdates
2-Potassium tetraperoxomolybdate
2-Sodium tetraperoxomolybdate
Metal Picramates
Palladium picramate
Uranyl picramate
Nitroaryl Compounds
N-Chloro-4-nitroaniline
Nitrogenous Base Nitrite Salts
Methylammonium nitrite
aci-Nitroquinonoid Compounds
Sodium 1,4-bis(aci-nitro)-2,5-cyuclohexadienide
aci-Nitro Salts
Ammonium aci-nitromethanide
Dipotassium aci-dinitromethanide
Thallium aci-phenylnitromethanide
Nitroso Compounds
Dinitrosylnickel
Ehtyl N-methyl-N-nitrosocarbamate
Potassium nitrosodisulfate
N—S Compounds
Disulfur dinitride
Potassium sulfurdiimidate
Tetrasulfur tetranitride
Thiotrithiazyl nitrate
Organic Acids
Picric acid
Trinitroresorcinol

Organic Azides
Diazidomethyleneazine
Picryl azide
Vinyl azide
Organolithium Reagents
o-Trifluoromethyl phenyllithium
m-Bromo phenyllithium
Organomineral Peroxides
Bis(triethyltin) peroxide
Diethylhydroxotin hydroperoxide
Oximes
Bromoacetone oxime
Hydroxycopper glyoximate
Potassium cyclohexanehexone 1,3,5-trioximate
Oxosalts of Nitrogenous Bases
Ammonium tetranitroplatinate (II)
Diamminepalladium (II) nitrate
1,2-Diammonioethane nitrate
Ozonides
trans-2-Butene ozonide
Ethylene ozonide (1,2,4-trioxolane)
Trifluoroethylene ozonide
Perchlorate Salts of Nitrogenous Bases
Pyridinium perchlorate
Teteraethylammonium perchlorate
Perchloramide Salts
Barium perchloramide
Mercury (II) N-perchloryl benzylamide
Silver perchlorylamide
Perchloryl Compounds
2,6-Dinitro-4-perchlorylphenol
Perchloryl fluoride
N-Perchloryl piperidine
Peroxyacid salts
Calcium peroxodisulfate
Potassium tetraperoxomolybdate

Tetramethylammonium pentaperoxodichromate
Peroxyacids
Benzenperoxyselennic acid
Peroxyacetic acid
Peroxyformic acid
Peroxycarbonate esters
O-O-tert-Butyl isopropyl monoperoxycarbonate
Diallyl peroxydicarbonate
Dimethyl peroxydicarbonate
Phosphorus esters
Diethyl phosphite
Dibenzyl phosphorchloridate
Picrates
Nickel picrate (anhydrous)
S-7-Methylnonylthiouronium picrate
Sodium picrate
Platinum Compounds
Amminedecahydroxydiplatinum
cis-Diammineplatinum (II) nitrate
Trimethylplatinum hydroxide
Poly(dimercuryimmonium) Compounds
Poly(dimercuryimmonium picrate)
Poly(dimercuryimmonium permanganate)
Poly(dimercuryimmonium trinitrobenzoate)
Polymerization (violent)
Acrylic acid
Ethylene oxide
Vinyl acetate
Polynitroalkyl Coumpounds
Dinitroacetonitrile
Hexanitroethane
Potassium trinitromethanide
Polynitroaryl Compounds
5,6-Dinitro-2-dimethyl aminopyrimidinone
4-Nitro-1-picryl-1,2,3-triazole

2,4,6-Trinitrotolune
Silver Compounds
Silver nitride (fulminating silver)
Disilver ketenide
Phenylsilver
Silver azide
Silver Osmate
Strained-Ring Compounds
2-Azatricyclo[2.2.102,6]hept-7-yl perchlorate
Dicyclopropyldiazomethane
Prismane
Tetrazoles
5-Aminotetrazole
Silver and mercury salts of 5-nitrotetrazole
Tetrazole
Triazoles
3-Diazo-5-phenyl-3H-1,2,4-triazole
4-Hydroxy-3,5-dimethyl-1,2,4-triazole
1,2,3-Triazole

Chemicals that May Deteriorate to Hazardous Conditions

The following is a selection of chemicals that can deteriorate to a dangerous condition with age under common storage conditions

From M.J. Pitt and E. Pitt, Handbook of Laboratory Waste Disposal, Ellis Horwood Publisher, UK, 1985

2-acetylfuran
acetaldehyde diethyl acetal
acetyl peroxide
ammonium dichromate
anethole
anisaldehyde
anisole

benzoyl peroxide
1-butoxyethylacetate
n-butyl glycidyl ether
n-butyl ether
t-butyl hydroperoxide

cellosolve
chromium trioxide
cumene
cyclohexene
cyclopentadiene
cyclopentene

1,1-diethoxyethane
1,2-dimethoxyethane
1,4-dioxane
2,4-dinitrophenol
2,4-dinitrophenylhydrazine
decahydronaphthalene
decalin
di-isoamyl ether
di-isobutyl ether
di-isopropyl ether
dibenzyl ether
dicyclopentadiene
diethyl azidoformate
diethyl ether
diethylacetal
diethylazodicarboxylate
diethyleneglycol dimethyl ether
diglyme
dihydropyran
dimethoxymethane
diphenyl ether

2-ethoxyethanol
2-ethoxyethyl acetate
ethyl cellosolve
ethylene glycol monomethyl ether
ethylene glycol monoethyl ether
ethylene glycol dimethyl ether
ethylene glycol monobutyl ether
ethylene glycol ether acetate

furan

glyme iodine pentoxide

isoamyl ether
isobutyl ether
isopentyl ether
isopropyl alcohol

2-methoxyethanol
magnesium perchlorate
mercury fulminate
methyl cellosolve
methyl ethyl keton peroxide
methyl isobutyl ketone
methyl vinyl ketone
nitromethane

peracetic acid
perchloric acid
picric aid
picryl chloride
picryl sulphonic acid
potassium (metal)
potassium amide
potassium chlorate
propargyl bromide
propargyl chloride

sodamide
sodium amide
sodium perchlorate
sodium chlorate
sodium metal dispersions
sodium chlorite
styrene
tetralin
trinitrobenzene sulphonic acid
trinitrobenzene

urea nitrate
vinyl pyridine
vinyl acetate
vinylidene chloride

Chemicals That May Explode Due to Over-Pressurized Container

From M.J. Pitt and E. Pitt, Handbook of Laboratory Waste Disposal, Ellis Horwood Publisher, UK, 1985. Formic acid & phenol have been added to list.

Aluminum chloride
Ammonia solution
Ammonium hydroxide
Ammonium persulfate
Anisyl chloride
Aqua regia
Benzenesulfonyl chloride
Bleach
Bleaching powder
Calcium carbide
Calcium hydride
Calcium hypochlorite
Chloroform
Chromic acid
Cumene hydroperoxide
Cyclohexane
Diethyl pyrocarbonate
Dimethylamine
Formic acid
Hydrogen peroxide
Lauroyl peroxide
Lithium aluminum hydride
Lithium hydride
Nitric acid
Nitrosoguanidine
Peracetic acid
Phenol
Phosphorus trichloride
Potassium Persulfate
Silicon tetrachloride
Sodium borohydride
Sodium dithionite
Sodium hydride
Sodium hydrosulfite
Sodium hypochlorite
Sodium peroxide
Sodium persulfate
Thionyl chloride
Urea peroxide
Zinc

Appendix E: Peroxidizable Compounds

Testing Schedule

There are four classes of peroxide-forming chemicals based upon the peroxide formation hazard:

- Class A – Severe Peroxide Hazard
- Class B – Concentration Hazard
- Class C – Shock and Heat Sensitive
- Class D – Potential Peroxide-Forming Chemicals

	Class A	**Class B**	**Class C**	**Class D**
Date Opened	3 months	6 months	6 months	1 year

Class A – Severe Peroxide Hazard

Spontaneously decompose and become explosive with exposure to air without concentration.

Butadiene (liquid monomer)	Isopropyl ether	Sodium amide (sodamide)
Chloroprene (liquid monomer)	Potassium amide	Tetrafluoroethylene (liquid monomer)
Divinyl acetylene	Potassium metal	Vinylidene chloride

Class B – Concentration Hazard

Require external energy for spontaneous decomposition. Form explosive peroxides when distilled, evaporated or otherwise concentrated.

Acetal	Diethylene glycol dimethyl ether (diglyme)	4-Methyl-2-pentanol
Acetaldehyde	Diethyl ether	2-Pentanol
Benzyl alcohol	Dioxanes	4-Penten-1-ol
2-Butanol	Ethylene glycol dimethyl ether (glyme)	1-Phenylethanol
Cumene	uran	2-Phenylethanol
Cyclohexanol	-Heptanol	2-Propanol
Cyclohexene	2-Hexanol	Tetrahydrofuran
2-Cyclohexen-1-ol	Methylacetylene	Tetrahydronaphthalene
Decahydronaphthalene	3-Methyl-1-butanol	Vinyl ethers
Diacetylene	Methylcyclopentane	Other secondary alcohols
Dicyclopentadiene	Methyl isobutyl ketone	

Class C – Shock and Heat Sensitive

Highly reactive and can auto-polymerize as a result of internal peroxide accumulation. The peroxides formed in these reactions are extremely shock and heat sensitive.

Acrylic acid	Chlorotrifluoroethylene	Vinyl acetate
Acrylonitrile	Methyl methacrylate	Vinylacetylene (gas)
Butadiene (gas)	Styrene Vinylpyridine	Vinyladiene chloride
Chloroprene	Tetrafluoroethylene (gas)	Vinyl chloride (gas)

Class D – Potential Peroxide Forming Chemicals

May form peroxides but cannot be clearly categorized in Class A, B, or C.

Acrolein	p-Chlorophenetole	4,5-Hexadien-2-yn-1-ol
Allyl ether	Cyclooctene	n-Hexyl ether
Allyl ethyl ether	Cyclopropyl methyl ether	o.p-Iodophenetole
Allyl phenyl ether	Diallyl ether	Isoamyl benzyl ether
p-(n-Amyloxy)benzoyl chloride	p-Di-n-butoxybenzene	Isoamyl ether
n-Amyl ether	1,2-Dibenzyloxyethane	Isobutyl vinyl ether
Benzyl n-butyl ether	p-Dibenzyloxybenzene	Isophorone
Benzyl ether	1,2-Dichloroethyl ethyl ether	b-Isopropoxypropionitrile
Benzyl ethyl ether	2,4-Dichlorophenetole	Isopropyl-2,4,5-trichlorophenoxy acetate
Benzyl methyl ether	Diethoxymethane	n-Methylphenetole
Benzyl-1-napthyl ether	2,2-Diethoxypropane	2-Methyltetrahydrofuran
1,2-Bis(2-chloroethoxyl)ethane	Diethyl ethoxymethylenemalonate	3-Methoxy-1-butyl acetate
Bis(2-ethoxyethyl)ether	Diethyl fumarate	2-Methoxyethanol
Bis(2-(methoxyethoxy)ethyl) ether	Diethyl acetal	3-Methoxyethyl acetate
Bis(2-chloroethyl) ether	Diethylketene	2-Methoxyethyl vinyl ether
Bis(2-ethoxyethyl) adipate	Diethoxybenzene (m-,o-,p-)	Methoxy-1,3,5,7-cyclooctatetraene
Bis(2-methoxyethyl) carbonate	1,2-Diethoxyethane	b-Methoxypropionitrile
Bis(2-methoxyethyl) ether	Dimethoxymethane	m-Nitrophenetole
Bis(2-methoxyethyl) phthalate	1,1-Dimethoxyethane	1-Octene
Bis(2-methoxymethyl) adipate	Di(1-propynl) ether	Oxybis(2-ethyl acetate)
Bis(2-n-butoxyethyl) phthalate	Di(2-propynl) ether	Oxybis(2-ethyl benzoate)
Bis(2-phenoxyethyl) ether	Di-n-propoxymethane	b,b-Oxydipropionitrile
Bis(4-chlorobutyl) ether	1,2-Epoxy-3-isopropoxypropane	1-Pentene
Bis(chloromethyl) ether	1,2-Epoxy-3-phenoxypropane	Phenoxyacetyl chloride
2-Bromomethyl ethyl ether	p-Ethoxyacetophenone	a-Phenoxypropionyl chloride
beta-Bromophenetole	1-(2-Ethoxyethoxy)ethyl acetate	Phenyl-o-propyl ether
o-Bromophenetole	2-Ethoxyethyl acetate	p-Phenylphenetone
p-Bromophenetole	(2-Ethoxyethyl)-a-benzoyl benzoate	n-Propyl ether
3-Bromopropyl phenyl ether	1-Ethoxynaphthalene	n-Propyl isopropyl ether
tert-Butyl methyl ether	o,p-Ethoxyphenyl isocyanate	Sodium 8-11-14-eicosatetraenoate
n-Butyl phenyl ether	1-Ethoxy-2-propyne	Sodium ethoxyacetylide
n-Butyl vinyl ether	3-Ethoxypropionitrile	Tetrahydropyran
Chloroacetaldehyde diethylacetal	2-Ethylacrylaldehyde oxime	Triethylene glycol diacetate

2-Chlorobutadiene	2-Ethylbutanol	Triethylene glycol dipropionate
1-(2-Chloroethoxy)-2-phenoxyethane	Ethyl-b-ethoxypropionate	1,3,3-Trimethoxypropene
Chloroethylene	Ethylene glycol monomethyl ether	1,1,2,3-Tetrachloro-1,3-butadiene
Chloromethyl methyl ether	2-Ethylhexanal	4-Vinyl cyclohexene
beta-Chlorophenetole	Ethyl vinyl ether	Vinylene carbonate
o-Chorophenol	2,5-Hexadiyn-1-ol	

References:
National Safety Council: Data Sheet I-655 Rev. 87
NFPA: NFPA 432, Code for the Storage of Organic Peroxide Formulations
Reactive Hazards Reduction, Inc. http://www.rhr-inc.com/
FDNY: 3 RCNY Chapter §10-01 – Chemical Laboratories

Appendix F: UBC Hazard Control Assessment Guide

If a hazard exists, there must be a means of controlling it. There are 4 types of controls that are available which must be evaluated in the order given: elimination or substitution, engineering, administrative (e.g. procedures, posters, work schedule, etc.) and personal protective equipment.

Supervisor Name: _____

Laboratory Number: _____

Review the "type of hazard" column check the hazards applicable to your lab, for each hazard checked, mark the type of controls already implemented in your lab

	Type of Hazard	**Type of Controls**
1.	☐ **General**	☐ Hazard assessment performed by supervisor ☐ Supervisor ensure proper PPE Used ☐ Supervisor ensure that working procedures and protocols are developed for lab specific hazard operations
2.	☐ **Hazardous Materials Used and Stored**	☐ Safety Manual Procedures are followed: ☐ WHMIS ☐ Safe Handling, Use & Storage of Hazardous Chemicals ☐ Personal Protective Equipment ☐ Personnel receive ☐ Laboratory Chemical Safety training ☐ On the job task specific training ☐ Lab specific protocols developed and followed ☐ Monthly safety inspection performed
3.	☐ **Compressed gases used or generated** ☐ Flammable ☐ Oxidizers ☐ Toxic ☐ Corrosive ☐ Reactive	☐ Safety manual procedure, Safe Handling, Use & Storage of Hazardous Chemicals- Compressed gas, followed ☐ Minimize inventory ☐ Proper securing and transportation ☐ Signage ☐ Leak test ,and storage in exhausted enclosures for hazardous gases ☐ Inspected and dated ☐ Monitors and alarms
4.	☐ **Flammable materials**	☐ Safety manual procedure, Safe Handling, Use & Storage of Hazardous Chemicals- Flammable & combustible materials, followed ☐ Material kept away from heat spark and open flame ☐ Minimum quantity kept in work area ☐ Volume limits observed ☐ Storage in approved containers, cabinets and spark proof refrigerators ☐ Stored away from oxidizers ☐ Proper labels on containers and cabinets ☐ Proper fire extinguishers in place

	Type of Hazard	Type of Controls
5.	☐ **Oxidizing materials**	☐ Safety manual procedure, Safe Handling, Use & Storage of Hazardous Chemicals- Oxidizing materials, followed ☐ Barriers are used to isolate from potential violent reaction ☐ Only minimum amount necessary used and stored in work area ☐ Kept away from incompatibles as reducing agents, flammable and combustible materials, organic acids
6.	☐ **Toxic materials**	☐ Safety manual procedure, Safe Handling, Use & Storage of Hazardous Chemicals- Toxic materials, followed ☐ Worker aware of the primary route of entry for materials used ☐ Appropriate Personal Protective Equipment and engineering controls are used ☐ The quantities used are minimized ☐ Signs and symptoms of acute exposure are observed ☐ Materials toxicity and potential chronic effects reviewed ☐ Storage according to manufacturer's recommendations, away from incompatible chemicals
7.	☐ **Corrosives**	☐ Safety manual procedure, Safe Handling, Use & Storage of Hazardous Chemicals- Corrosives, followed ☐ Proper PPE used (goggles, and splash shield) ☐ Ice bath or cold water available to control exothermic reactions ☐ Additional hazards (toxicity, reactivity are considered) ☐ Upon exposure immediate action taken to wash away the material ☐ Eye wash station and safety showers are in place, accessible
8.	☐ **Reactive materials** ☐ Pyrophoric materials ☐ Water reactive ☐ Shock sensitive materials	☐ Safety manual procedure, Safe Handling, Use & Storage of Hazardous Chemicals- Reactive materials, followed ☐ Work bench quantity restricted (amount needed for that day only) ☐ Equipment shielded, and operator wear suitable Personal Protective Equipment ☐ Work is isolated from worker by distance ☐ Storage as required by properties free of stability compromising conditions (i.e. shock, vibration, incompatible chemicals, elevated temperature, rapid temperature change) ☐ MSDS reviewed to determine reactivity and compatibility
11.	☐ **Hazardous Waste Generated**	☐ Appropriate containers used ☐ Container closed when not in use, properly labeled ☐ Flammable liquids and biohazard waste containers with proper tags, and generator bar code stickers ☐ UBC hazardous waste procedures are followed ☐ Sanitary sewer discharge prohibitions are observed

	Type of Hazard	Type of Controls
		☐ Traps and back flow restrictors used as necessary ☐ Worker trained on emergency procedure
12.	☐ **Energy Source/Energy Failures** ☐ Heating and cooling systems ☐ High voltage ☐ Machinery ☐ Water/air ☐ Ventilation ☐ Automatic controls or equipment	☐ Automatic shut off systems for machinery, power ☐ Flow sensors and shut off valves for water, air, gases ☐ Backup system for power, water, air ☐ Lockout/ tag out procedures in place and followed ☐ Process specific handling and emergency procedures developed and followed
13.	☐ **Physical Hazard**	
	☐ **Musculoskeletal Injury (MSI)**	☐ Worker aware of factors causing MSI and signs and symptoms of MSI ☐ Work station arranged to fit task and employee ☐ Proper PPE used ☐ Worker implement proper posture while performing tasks ☐ Sufficient space provided to perform task safely ☐ Safe lifting rules and weight limits are observed
	☐ **Extreme temperature**	☐ Proper PPE, and materials handling tools used
		☐ Proper PPE available and used ☐ Proper waste containers available and used
	☐ **Trip/ slip and fall Hazards**	☐ Exists and isles free of tripping hazard ☐ Walking surface unobstructed, dry ☐ Step stool available for out of reach items
	☐ **Equipment Hazard** ☐ Physical hazard ☐ Harmful emission ☐ Hazardous waste generation ☐ Contamination backflow to water system ☐ Electrical hazard	☐**Operation manuals and procedures, routine inspections** ☐ Hazard identification on equipment (signs/labels) ☐ Safe guars ☐ Shields ☐ Isolation by location ☐ Exhaust ventilation ☐ Proper collection drainage and disposal ☐ Vacuum break device ☐ Lockout tag out procedure followed, guards in place
	☐ **Other**	

Appendix G: Personal Protective Equipment Hazard Assessment

Chemical Hazards			
Check All That Apply	**Task**	**Potential Hazard**	**Recommended PPE**
☐	Working with ml amount of less hazardous chemicals (TLV >100).	Slight skin or eye damage	Safety glasses Light chemical resistant gloves, closed shoe, pants
☐	Working with small volumes of corrosive liquids (< 1 liter).	Skin or eye damage	Safety glasses or goggles Light chemically resistant gloves Lab coat, closed shoe, pants
☐	Working with large volumes of corrosive liquids (> 1 liter), acutely toxic corrosives, or work which creates a splash hazard	Large surface area skin or eye damage, poisoning, or great potential for eye and skin damage	Safety goggles and face shield Heavy chemically resistant gloves Lab coat, closed shoe, pants, and chemically resistant apron
☐	Working with small volumes of organic solvents (< 1 liter).	Skin or eye damage Slight poisoning potential through skin contact	Safety glasses or goggles Light chemically resistant gloves Lab coat, closed shoe, pants
☐	Working with large volumes of organic solvents (> 1 liter), very dangerous solvents, or work which creates a splash hazard	Major skin or eye damage, or potential poisoning through skin contact	Safety goggles and face shield Heavy chemically resistant gloves Lab coat, closed shoe, pants, and chemically resistant apron
☐	Working with toxic or hazardous chemicals (solid or liquid).	Potential skin or eye damage, potential poisoning by skin contact.	Safety glasses (goggles for large quantities), light chemically resistant gloves, lab coat, closed shoe, pants.
☐	Working with acutely toxic or hazardous chemicals (solid or liquid).	Great potential skin or eye damage, great potential poisoning through skin contact.	Safety goggles, appropriate heavy chemically resistant gloves, lab coat, closed shoe, pants Coveralls and booties if necessary.
☐	Working with explosives.	Skin or eye damage from flying projectiles or chemicals.	Blast shield, safety goggles or full face shield, chemically resistant gloves, lab coat, closed shoe, pants.
☐	Working with chemical dusts.	Skin or eye damage, respiratory damage.	Safety glasses or goggles, appropriate gloves, lab coat, closed shoes or boots if necessary, pants, Approved respiratory protection
☐	Chemical spill cleanup.	Skin or eye damage, respiratory damage.	Safety glasses or goggles, appropriate gloves, lab coat, closed shoes or boots, pants, (contact hazmat for clean-up if respiratory protection necessary)

Physical Hazards			
Check	**Task**	**Potential Hazard**	**Recommended PPE**
☐	Working with cryogenic liquids.	Major skin, tissue, or eye damage.	Safety glasses or goggles for large volumes, heavy insulated gloves, lab coat, closed shoe, pants.
☐	Working with very cold equipment or dry ice.	Frostbite, hypothermia.	Safety glasses, insulated gloves & warm clothing, lab coat, closed shoe, pants.
☐	Working with hot liquids, equipment, open flames (autoclave, bunsen burner, water bath, oil bath).	Burns resulting in skin or eye damage.	Safety glasses or goggles for large volumes, insulated gloves, lab coat, closed shoe, pants.
☐	Instrument repair	Eye damage from foreign objects.	Safety glasses, no loose clothing or jewelry.
☐	Metal or woodworking.	Eye damage from foreign objects, lacerations.	Safety glasses, gloves, no loose clothing or jewelry.
☐	Working in nuisance dusts.	Skin or eye damage, respiratory damage.	Safety goggles, appropriate gloves, lab coat, closed shoes or boots if necessary, pants, NIOSH approved dust mask or other respiratory protection
☐	Glassware washing.	Lacerations.	Heavy rubber gloves, lab coat, closed shoes, pants.
☐	Working with sharp objects or potential for glass braking	Cuts	Cut resistant gloves, safety glasses
☐	Working with loud equipment, noises, sounds, or alarms, etc.	Potential ear damage and hearing loss.	Ear plugs or headphones as necessary.

Appendix H: Spill Kit Check List

The following are suggested items to be included in a spill kit:

Quantity	Description
2 each	Plastic liners
1 each	Instruction Booklet
1 each	Safety Flashlight
1 each	Printed Floor Sign (slippery when wet)
1 roll	Barricade tape
2 each	Chemical Spill Clothing Kit - MUST BE SEALED
10 each	Spill Control Pillows, 1 litre size
1-10 litres	Damming Material (unreactive, absorbent such as vermiculite)
1 each	Acid Neutralizer shaker, 2.8 kg (Spill X -A)
1 each	Caustic Neutralizer Shaker, 2.8 kg (Spill X- C)
1 each	Solvent Absorbent Shaker, 2.8 kg (Spill X- S)
1 box	Mercury/VAP ABSORB
1 each	Tongs, 20" long (for picking up broken/contaminated glass)
1 each	Mop Bucket, 35 quart
1 each	Wringer
1 each	24 ounce Mop Head and Handle
1 each	Spill Squeegee, Floor Size, 18" Head
1 each	Spill Squeegee, Bench Size, 8" Head
1 each	Polypropylene Broom
1 each	Bench Brush
1 each	Dust Pan 1 roll Chem/Kleen-Ups Towels, 9 3/4" X 100 ft. roll
1 each	Glass Disposal Box, 8" X 8" X 10"
5 each	Hazardous Waste Disposal Bags 12" X 18"
1 each	Sponge
1 each	Liquid Cleaner, 32 ounce
1 each	Bleach, 1 gallon
1 roll	pH Paper
1 roll	Barricade Tape, 100 feet
1 each	Cover, for CART

Checked by:_____
Date:_____

1) *Note any shortages*
2) *Replace ASAP*
3) *If Clothing kit disturbed, check item by item.*

Personal Protective Clothing Check List

Quantity	Description
1 each	Total Body Coverall, Polylaminated TYVEK
2 pair	Foot Covers, Disposable, Polyethylene
1 pair	Nitrile Gloves
1 package	Disposable Polyethylene Gloves
1 pair	Chemical Splash Goggles, Fog Free Lens
1 each	Hydrogen Fluoride Respirator
1 each	Dust and Mist Respirator
1 each	Toxic and Hazardous Chemicals In Industry Chart, Pocket Size

Checked by:_____
Date:_____

The Clothing Kit must be sealed up again with the Tape provided for this purpose.
Note: When a *cartridge respirator* is required for chemical spill clean-up, only those who have been *trained* and *fit-tested* are authorized to do so. For this reason, cartridge respirators are *not included in the spill kit.*

Appendix I: Project Hazard and Control Analysis

Department name: _____

Hazard Grade: High ( ) (potentially life threatening)
Medium ( ) (potential for significant equipment or building damage)
Low ( ) (minor equipment damage)

Equipment Type	
Previous Inspection Date	
Room No.	
Current Inspection Date	
Experimenter(s)	
Inspected By	
Advisor(s)	

Potential Hazards	Y/N	Control Measures
High pressure or Vacuum		
High temperature		
High voltage		
Risk of explosion		
Toxic materials		
Reactive/oxidizing materials		
Cryogenics/compressed gases		
Solvents		
Loss of air		
Loss of water		
Loss of power		
Other		

Part II. Specify potential leak hazards: _____

Part III. Spill Control for the following types of spills is available: _____

Part IV. List principle hazardous chemicals used

Item	Quantity	MSDS Available (✓)	MSDS Reviewed (✓)

Part V. Waste generation information

Type of Waste	Quantity	Disposal Method Available (describe)

Part VI. Safety Information

Emergency Contact Information
Name:
Phone number:
Location:

Emergency Shutdown Procedures posted:
Yes ( ) No ( ) Location:

Emergency Safety Equipment
Fire extinguisher location:
Eye wash fountain location:
Emergency shower location:

First aid station location:

Required Personal Protective Equipment Available

Eye protection: Yes ( ) No ( ) Location:
Foot protection: Yes ( ) No ( ) Location:
Hand protection: Yes ( ) No ( ) Location:
Apron/lab coat: Yes ( ) No ( ) Location:
Respirator: Yes ( ) No ( ) Location:

Part VII. Historical safety problems_____

Part VIII. Inspection Committee Recommendations

Mandatory: _____

Optional: _____

Other Remarks: _____

Appendix J: UBC Chemical Laboratory Safety Check List

Laboratory Supervisor: _____ Room Number: _____

Inspected By: _____ Date: _____

The following inspection report identifies deficiencies found by the inspection team.

ITEM	YES	NO	N/A	COMMENTS
A. EMERGENCY and INFORMATION MATERIAL				
1. Emergency procedures posted and legible				
- Fire, spills, injuries, earthquake	☐	☐	☐	
2. MSDS information posted	☐	☐	☐	
3. Chemical Safety Manual available	☐	☐	☐	
4. Chemical inventory, current (<1 year)	☐	☐	☐	
5. Monthly inspections posted and up-to-date	☐	☐	☐	
6. Shower available and accessible	☐	☐	☐	
7. Eyewash available and accessible	☐	☐	☐	
8. Eye wash tested regularly (minimum, bi-weekly)	☐	☐	☐	
9. Fire extinguisher present and accessible	☐	☐	☐	
10. Fire extinguisher seal intact; date tested	☐	☐	☐	
11. Spill kit available and stocked.	☐	☐	☐	
B. FIRST AID				
12. First aid kit available and stocked	☐	☐	☐	
-Inventory list available	☐	☐	☐	
13. Treatment record sheet available and used	☐	☐	☐	
C. PERSONAL PROTECTION				
14. Safety glasses available and worn	☐	☐	☐	
15. Laboratory coats and gloves available and worn	☐	☐	☐	
16. No bare legs	☐	☐	☐	
17. Substantial footwear worn	☐	☐	☐	
18. Facial shields available and in good condition	☐	☐	☐	
19. Blast shields available and in good condition	☐	☐	☐	
20. Respirator(s) available	☐	☐	☐	
21. Respirator user(s) trained & fit-tested	☐	☐	☐	
22. Vacuum ballasts/Dewar flasks taped or meshed	☐	☐	☐	
D. HOUSEKEEPING				
23. Bench tops and sink areas tidy	☐	☐	☐	
24. Tripping hazards absent, passageways clear	☐	☐	☐	
25. Laboratory exits clear and doors unlocked	☐	☐	☐	
26. Food and drink absent	☐	☐	☐	
27. Chipped or broken glassware not in use	☐	☐	☐	
28. Friable asbestos absent	☐	☐	☐	
29. Step-ladder available for out-of-reach items	☐	☐	☐	
30. "No Eating/Drinking/Smoking" signs posted	☐	☐	☐	
E. WASTE CONTAINERS				
31. "Glass" refuse containers labeled	☐	☐	☐	
32. "Glass" segregated from general refuse	☐	☐	☐	
33. Needles and sharps in "Sharps" container	☐	☐	☐	

34. Bulk solvent-waste containers closed and labeled	☐	☐	☐
-Halogenated and non- Halogenated segregated	☐	☐	☐
-Bulk solvent-waste stored in flammable storage cabinet	☐	☐	☐
35. Recyclable solvents segregated	☐	☐	☐
36. Interim solvent waste containers closed and <1 litre	☐	☐	☐
37. Ethidium bromide waste segregated	☐	☐	☐
38. Photographic chemical waste procedures followed	☐	☐	☐
39. Are you aware of UBC's Chemical Exchange Program?	☐	☐	☐
F. COMPRESSED GAS CYLINDERS			
40. Indevidually secured to wall or bench with belt or chain	☐	☐	☐
41. Lecture bottles stored upright or slanted/secure	☐	☐	☐
G. FUME HOODS			
42. Sash at recommended height and air flow on	☐	☐	☐
43. Area within and under hood tidy	☐	☐	☐
44. Carcinogens permitted	☐	☐	☐
H. ELECTRICAL APPARATUS			
45. Vacuum pumps stored safely and belts guarded	☐	☐	☐
46. Refrigerator spark-proof (or "***NO Flammables"*** sign posted & flammables are absent)	☐	☐	☐
47. Frayed or cracked electrical cords absent	☐	☐	☐
48. Make-shift wiring absent	☐	☐	☐
I. RUBBER OR PLASTIC TUBING			
49. Cracked/brittle/pinched tubing absent	☐	☐	☐
50. Water hoses wired at all connectors	☐	☐	☐
51. Water taps safeguarded against "suck-back" (or "***NO TUBING"*** sign posted)	☐	☐	☐
J. CHEMICAL LABORATORIES			
52. Solvent storage cabinet available and closed	☐	☐	☐
53. Solvent containers closed and labeled	☐	☐	☐
54. Solvent containers ***outside*** safety cabinet, < 25 L	☐	☐	☐
55. Solvent-still contents labeled	☐	☐	☐
56. Reagent chemicals stored securely (lips on shelves or doors on cupboards)	☐	☐	☐
57. Chemical containers intact.	☐	☐	☐
Proxide forming chemicals:			
58. Stored (& used) out of direct sunlight	☐	☐	☐
59. Containers display opening date	☐	☐	☐
60. Checked for peroxides (3 to 12 months)	☐	☐	☐
61. Labels compliant with WHMIS	☐	☐	☐
62. Chemical labels intact, legible, not overwritten	☐	☐	☐
63. Cleaning baths labeled	☐	☐	☐
64. Carcinogens/Corrosives/Flammables labeled	☐	☐	☐
65. Incompatible materials separated	☐	☐	☐
66. Perchloric acid absent/used in special fume hood	☐	☐	☐

PLEASE ENSURE THAT CORRECTIONS ARE MADE BY:_____

Supervisor:_____

(*Please sign after violations have been corrected*)

UPON CORRECTION OF VIOLATIONS, PLEASE RETURN TO LOCAL SAFETY COMMITTEE

Appendix K: Monthly Safety Checklist

Room: _____

Due Date/Time for Monthly Inspection: _____

Supervisor's Name: _____

Designate's Name (where appropriate): _____

To ensure that this lab is always a safe workplace, the following items on this list must be checked at least once every month.

Item	**Month:**			**Month:**		
	Yes	**No**	**Action Taken**	**Yes**	**No**	**Action Taken**
1. Personal protective equipment available and used.						
2. Good housekeeping; food and drink absent.						
3. Aisles and exits clear and free of tripping hazards.						
4. Water hoses wired or clamped; gas cylinders clamped.						
5. Fume hoods neat and functioning.						
6. Flammable solvents < 25 L in open lab.						
7. Peroxidizable compounds dated upon opening and tested at appropriate intervals						
8. Proper labelling of chemicals; labels clear and legible.						
9. Compatible storage of chemicals.						
10. Free of electrical hazards						
11. Sink traps, eye wash fountains flushed weekly.						
Checked (✓) by (initials)						

Glossary of Terms

acid	a substance that increases the concentration of hydronium ions (H30+) in solution; acts as a proton donor; has a pH of less than 7
acute	a rapid onset
aerosol	a suspension of fine solid particles or liquid droplets in a gas
asphyxiation	a condition of severely deficient supply of oxygen to the body
auto-ignition	spontaneous combustion without an ignition source
base	a substance that can accept hydrogen ions/ donate electron pairs; has a pH greater than 7
break-through	when referring to PPE it is when the protection is no longer effective in blocking a substance from making contact with the individual wearing said protection
Cardex	the index to periodicals subscribed to
caustic	a corrosive substance that will destroy or damage another surface or substance it comes in contact with
CCOHS	Canadian Centre for Occupational Health and Safety
ceiling limit	concentration of a substance in air which may not be exceeded at any time during the work period
chronic	long-lasting or recurrent
combustibility	measure of how easily a substance will set on fire (flash point>37.8degC)
condensation	the change of the physical state of matter from gaseous phase into liquid phase
controlled products	a material that exceeds hazard criteria for inclusion in the WHMIS hazard classes and divisions
corrosive	a substance that will destroy or damage another surface or substance it comes in contact with
cryogenic	a substance with a boiling point below -150degC at sea level
cytotoxin	an agent that possesses a specific destructive action on certain cells or that may be genotoxic, oncogenic, mutagenic, teratogenic, or hazardous to cells in any way
decomposition	the process where an unstable chemical breaks down into simpler chemicals
decontamination	the process of cleansing a surface, equipment or person to remove hazardous materials
distillation	a method of separating mixtures based on

	differences in their volatilities through boiling; it is a physical separation process, not a chemical reaction
endothermic	the process or reaction where energy is absorbed from the surroundings as heat; in chemical reactions this heat is converted into chemical bond energy
ESF	Environmental Services Facility
evaporation	the process of the phase transition from the liquid to gas phase that occurs at temperatures below the boiling temperature.
exothermic	the process or reaction where energy is released to the surroundings as heat
Explosives	materials that contains a great amount of stored energy that can produce a sudden expansion of the material after initiation, usually accompanied by the production of light, heat, sound, and pressure
flammability	measure of how easily a substance will set on fire (flash point<37.8degC)
flash point	temperature at which the vapor pressure of a liquid results in a vapor concentration great enough to ignite (flash) in the presence of a spark or flame
HEPA	High Efficiency Particulate Air
homogenous	uniform in composition or character
IDLH	Immediately Dangerous to Life or Health
infectious	detrimental colonization of a host organism by a foreign species
irritant	substance that causes inflammation or painful reaction
LC50	concentration required of a toxic substance to kill 50% of the members of a tested population
LD50	dose required of a toxic substance to kill 50% of the members of a tested population
LEL	Lower Explosive limit (as a concentration)
local	immediate area
MSDS	Material Safety Data Sheet
mutagen	physical or chemical agent that changes the genetic material, usually DNA, of an organism and increases the frequency of mutations above background
n95	a rating of respirators: filters 95% of airborne particles
narcotic	psychoactive compound with sleep-inducing effects

neutralizer	a substance that bring the pH of an acid or base
NIOSH	National Institute for Occupational Safety and Health
nitrocellulose	a highly flammable compound formed by nitrating cellulose through exposure to nitric acid or another powerful nitrating agent
oxidizer	a chemical compound that readily transfers oxygen atoms
oxoacid	an acid that contains oxygen
PEC	Potentially Explosive Chemical
Pesticide	a substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest
pH	a measure of the acidity or basicity of an aqueous solution
poison	a substance that can cause disturbances to organisms, usually by chemical reaction or other activity on the molecular scale
polymerization	a chemical reaction in which many small molecules (monomers) join together to form large, chain-like molecule (polymer)
ppm	parts per million
pyrophoric	a substance that will ignite spontaneously in air
reactivity	the rate at which a chemical substance tends to undergo a chemical reaction
reagent	substance or compound that is added to a system in order to bring about a chemical reaction or is added to see if a reaction occurs
reflux	a technique involving the condensation of vapors and the return of this condensate to the system from which it originated
reproductive toxin	a substance that effects reproductive organs or processes
respirator	a device designed to protect the wearer from inhaling harmful dusts, fumes, vapors, and/or gases
run-away reaction	a chemical reaction that cannot be controlled and/or contained
saponification	a chemical process that produces soap from fatty acid derivatives
SCBA	Self-Contained Breathing Apparatus
sensitizer	a chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical
solvent	a liquid, solid, or gas that dissolves another solid, liquid, or gaseous solute, resulting in a solution

	that is soluble in a certain volume of solvent at a specified temperature
STEL	Short Term Exposure Limit
suck-back	a process where a liquid is pulled from a vessel due to a vacuum
systemic	affecting the whole body
TDG	Transport of Dangerous Goods
teratogen	a substance that causes abnormalities in physiological development
TLV	Threshold Limit Value
Toxicity	the degree to which a substance can damage an organism
TWA	Time Weighted Average
UEL	Upper Explosive limit (as a concentration)
ULC	Underwriters' Laboratory of Canada
vapour pressure	the pressure exerted by a liquid's vapor when the liquid and vapor are in dynamic equilibrium
VFRS	Vancouver Fire and Rescue Services
VOC	volatile organic compound
WHMIS	Workplace Hazardous Material Information System