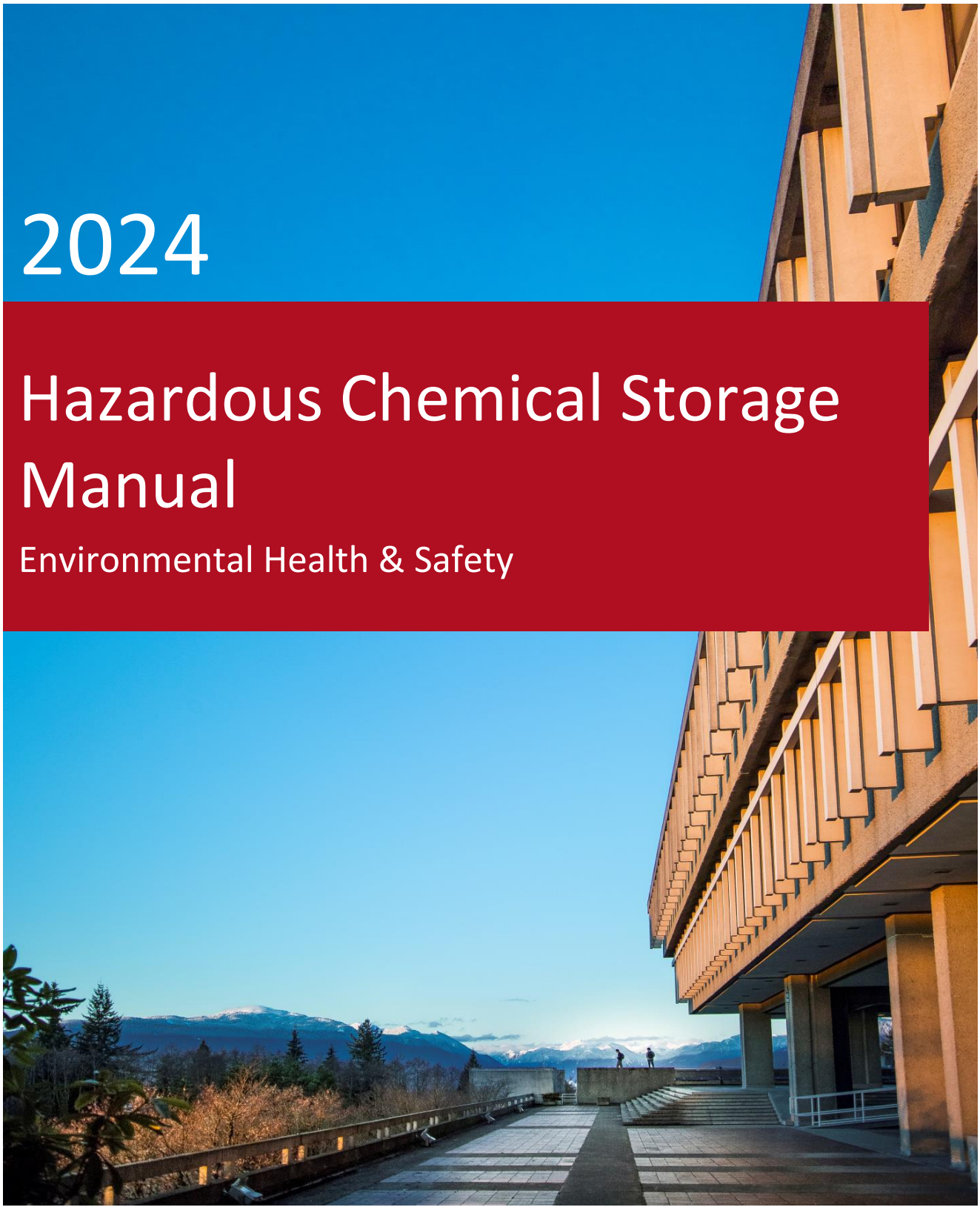
SFU SAFETY & RISK SERVICES
ENVIRONMENTAL HEALTH & SAFETY

2024

Hazardous Chemical Storage Manual

Environmental Health & Safety



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2024.02.23	Carol Wu	Workplace label information update.
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1. INTRODUCTION

Proper chemical storage is a complex and challenging component of laboratory management. Poor or incorrect chemical storage practices can result in inadvertent reactions between incompatible materials with potential to cause chemical exposure, injury, fire or explosion. Safe, effective chemical storage includes, but is not limited to, the creation of a detailed procedure for storage and emergency response, accurate inventory and labelling, and an understanding of chemical incompatibilities, which will enable:

1. Effective management of chemicals
2. Reduced risk of fire
3. Prevention of the inadvertent mixing of incompatible chemicals in the event of emergencies
4. Minimized exposure to toxic and corrosive chemicals, and
5. Compliance with relevant regulatory requirements.

Regulatory requirements relating to chemical storage come from a variety of sources, including, but not limited to WorkSafeBC Occupational Health and Safety Regulation (OHSR), BC Fire Code and National Fire Protection Association (NFPA) Codes and Standards. Simon Fraser University (SFU) complies with all applicable regulations and standards to protect human health and the environment.

SFU's Chemical Storage Manual is intended to promote the safe storage of chemicals by offering information on regulatory compliance and best practices for chemical labelling and general storage requirements, as well as specific storage and segregation information for certain types of chemicals. This Manual applies to all faculty, staff, students and visitors at the University who will be involved in the use and management of chemical storage in laboratories.

2. SCOPE

This manual details the elements of SFU's chemical storage procedures to ensure compliance with all relevant Federal, Provincial and Municipal regulations.

2.1 The scope of this manual is limited to chemicals stored in SFU laboratories.

2.2 For information about the storing of radioactive materials, see https://www.sfu.ca/srs/work-research-safety/research-safety/radiation-safety/program-manuals.html;

2.3 For information about storing biohazardous materials, see https://www.sfu.ca/srs/work-research-safety/research-safety/biosafety/program-manuals.html.

3. RESPONSIBILITIES

Ensuring regulatory compliance through robust University-wide practices for safe handling and storage of hazardous chemicals requires a collaborative commitment from senior administration, faculty, staff and students. The responsibilities to achieve the required engagement and compliance are outlined below.

3.1 DEANS, CHAIRS AND DIRECTORS

Deans, chairs and directors are responsible for:

- Ensuring the Hazardous Chemical Storage Manual (the 'Manual') is implemented in all departments and/or facilities under their authority; and
- Monitoring the management of hazardous chemical storage within their areas of responsibility and recommending measures for improvement, if necessary.

3.2 PRINCIPAL INVESTIGATORS, FACULTY, INSTRUCTORS AND SUPERVISORS

Principal investigators, faculty, instructors and supervisors are responsible for:

- Understanding and implementing the Manual, including conducting risk assessments of how to safely store hazardous chemicals in their workplace or laboratory;
- Ensuring personnel under their supervision (including, but not limited to, grad students, post-doctoral fellows, research assistants, teaching assistants, visiting scholars, co-op students, staff and undergraduate students) understand the elements of the Manual as it relates to their workplace or laboratory;
- Advising personnel under their supervision of the specific administrative and physical hazardous chemical storage requirements or provisions (e.g., requirements for inventories, quantity limits, secondary containment, and flammable storage or acid cabinets) that are needed to mitigate the specific hazards present in their workplace or laboratory;
- Ensuring personnel under their supervision have successfully completed all relevant hazardous chemical training offered by the University (e.g., Laboratory Safety Training);
- Providing specific training to personnel under their supervision for relevant hazards, including hazardous chemical storage provisions associated with the operations of their laboratories, and maintaining records of this training;
- Monitoring to ensure personnel under their supervision follow the requirements outlined in the Manual including required protocols and procedures relating to hazardous chemical storage;
- When required, take part in audits, inspections, and incident investigations, and maintain records; and
- Ensure corrective actions identified in their area of responsibility are implemented.

3.3 LABORATORY MANAGERS, POST-DOCTORAL FELLOWS, TECHNICIANS, COORDINATORS, AND STAFF

Laboratory managers, post-doctoral fellows, technicians, coordinators, and staff are responsible for:

- Understanding the Manual and relevant storage requirements with respect to specific types of hazardous chemicals in their workplace or laboratory;

- Using adequate procedures and equipment as required by the Manual to mitigate the risks with storing hazardous chemicals in their workplace or laboratory;
- Implement procedures to meet the relevant storage requirements assuring safety features and function, and to update procedures as needed;
- Informing their supervisors of their personal training needs and any safety concerns; and
- Ensuring students, volunteers, and visitors understand and follow the Manual and relevant procedures.

3.4 STUDENTS, VOLUNTEERS AND VISITORS

All individuals who work with hazardous chemicals are responsible for:

- Understanding and following the Manual with respect to hazardous chemical storage in their workplace or laboratory;
- Using the information they receive through education and training to ensure safe storage of hazardous chemicals;
- Assisting to maintain a safe work environment through assuring proper use and operation of the relevant storage requirements; and
- Informing their supervisors of their personal training needs and any safety concerns.

3.5 ENVIRONMENTAL HEALTH & RESEARCH SAFETY

The Department of Environmental Health & Research Safety is responsible for:

- Providing information and guidance to individuals and departments on the safe storage of hazardous chemicals at SFU;
- Providing training sessions on hazardous chemical storage, general laboratory safety, Workplace Hazardous Materials Information System (WHMIS) and Transportation of Dangerous Goods (TDG);
- Maintaining records of all training;
- Conducting periodic audits to ensure compliance with the Manual;
- Monitoring changes to hazardous chemical storage regulations and updating users; and
- Periodically reviewing and updating the Manual.

4. CHEMICAL LABELLING

All chemicals must be clearly labelled for the benefit of users and emergency personnel. Chemicals regulated by WHMIS provisions in provincial and federal legislation must have supplier labels which communicate specific health and safety information.

4.1 WORKPLACE LABELS

Workplace labels are required for hazardous products synthesized in the laboratory and for purchased chemicals when they are transferred to a smaller container or when a supplier label falls off or becomes illegible. These must contain, at minimum:

- Product identifier (chemical name);
- Information for the safe handling of the product;
- Referral to the Safety Data Sheet (SDS).

When the transferred material will all be used during one shift and is under the control of the person who decanted it, only the product identifier is required.

Labels must be clearly legible and understandable by all laboratory users. Any former labels or product identifiers must be removed from containers or otherwise defaced.

4.2 HAZARDOUS WASTE LABELS

Hazardous waste labels are required for hazardous waste being collected from SFU laboratories. Individual labels are available from EHS, Science Stores and Science Receiving. For more information see: https://www.sfu.ca/srs/work-research-safety/research-safety/lab-safety/hazardous-waste.html

4.3 OTHER LABELS

Labels for peroxide forming chemicals must be affixed to containers of these chemicals in order to track the date of receipt, date of opening and subsequent testing for peroxides. More information on peroxides can be found here.

All other chemicals should be labelled with the date of receipt. This helps track chemical usage in addition to providing a “freshness” indicator. It is also recommended practice to label each chemical with its storage location, to ensure it is returned to its proper place after each use.

5. CHEMICAL INVENTORY AND SIGNAGE

5.1 CHEMICAL INVENTORY

Establishing and maintaining a chemical inventory is the foundation for safe chemical segregation and storage in the laboratory. WorkSafeBC OHSR, Part 5, Section 5.98, states that “An inventory must be maintained which identifies all hazardous substances at the workplace in quantities that may endanger workers in an emergency including hazardous 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 the Safety Data Sheets (SDSs).”

The SFU Laboratory Hazard Inventory System allows laboratories to create and maintain an online inventory of chemicals that meets this regulatory requirement. The inventory system is also used to generate the laboratory door sign, which is mandatory for spaces that have hazardous chemicals (see Laboratory door sign). Hazardous items to be entered into the system include materials such as flammables, explosives, oxidizers, corrosives, gas cylinders, and chemicals causing serious

health effects. Non-hazardous items, for example, buffers, salts, amino acids, sugars, and growth media, do not need to be included in the inventory.

The online inventory system comprises information for each chemical such as:

- CAS number;
- Chemical name;
- Physical state;
- Molecular formula;
- Storage location in the laboratory;
- Approximate quantity and units of measure;
- NFPA ratings for flammability, health and reactivity hazards;
- WHMIS hazard pictogram(s); and
- Date record updated.

Depending on the specific needs of each lab, additional information may be tracked, such as:

- Synonym(s);
- Purchase date;
- Expiry date and/or Reminder date (e.g., for peroxide testing);
- Supplier name;
- Item product number;
- Lot or batch number;
- Category;
- Concentration; and
- Purity/grade.

Once an inventory is prepared, it must be reviewed at least annually to ensure it accurately reflects the chemicals in the laboratory. This review will serve as a reminder to:

- Check chemicals with limited shelf lives;
- Identify and remove expired or unwanted chemicals;
- Check the integrity of all storage vessels for cracks, aging, or leaks; and
- Prevent the unnecessary purchase of chemicals already on hand.

For more information about the SFU Laboratory Hazard Inventory System, see http://www.sfu.ca/srs/ehs/research-safety/general-lab-safety/hazard-inventory.html.

5.2 LABORATORY DOOR SIGN

At minimum of once per year, the laboratory inventory is used to generate a laboratory door sign, which provides important information for emergency personnel. This signage summarizes the nature and relative quantity of hazardous materials being stored in the laboratory, displays emergency contacts for the laboratory, and is generated directly from the online inventory system. For more information, see https://labhazindex.its.sfu.ca.

6. GENERAL GUIDELINES FOR SAFE STORAGE

6.1 BASIC REQUIREMENTS

The following basic storage requirements apply to all hazardous chemicals. The section Specific chemical hazards and segregation provides additional guidance for chemicals assigned in specific hazard classes.

- Chemicals must be stored according to chemical compatibility such that incompatible materials do not come in contact with each other in the event of a breakage or spill.
- In cases where it is not practical to store incompatible chemicals in physically separate locations, it is acceptable to segregate chemicals using glass, porcelain or heavy gauge plastic secondary containers. The secondary containers must be compatible with the material being stored and large enough to contain any spills.
- Store liquids separately from solids to minimize the possibility of mixing.
- Keep containers closed unless you are dispensing a chemical or adding to the container.
- Never store an open container with a funnel in it.
- Ensure that chemicals stored over a long period of time are placed in containers that will maintain their integrity.

6.2 STORAGE AREAS

- Inspect storage areas on an annual basis.
- Ensure storage areas have adequate lighting and ventilation, and are maintained at a consistent, cool temperature.
- Ensure chemical storage areas do not block aisles, hallways, doorways, exits or emergency equipment (e.g., eyewash, shower, pull stations, fire extinguisher).
- Do not store chemicals in or under a sink. This is to prevent corrosion of plumbing and any problems in the event of a plumbing leak or burst pipe.
- Do not store chemicals in a fume hood unless the fume hood is used exclusively for storage and is labelled as such.
- Do not store chemicals on the floor, on window ledges or balconies.
- Store heavy bottles on lower shelves (i.e., below bench height).

6.3 STORAGE SHELVES

- Ensure shelves are level, stable, chemical-resistant, secure and strong enough to support the weight of the stored containers.
- Shelving should be accessible with chemicals at eye level or lower.
- Shelves should have raised edges or rim guards (minimum 5 cm or 2 in) to prevent containers from falling. Bungee cords may be used for extra security.
- Shelves should be deep enough such that containers do not protrude over edges.

6.4 STORAGE EQUIPMENT

Using specially designed equipment for storage of flammables, acids, or corrosives allows a laboratory to meet the specific requirements (e.g., temperature, corrosion control, and absence of sparks) associated with many chemicals. Use only approved storage cabinets and label cabinets with the hazard class of the chemicals stored within.

6.4.1 Flammable storage cabinets

- Venting flammable storage cabinets is not recommended. However, in the event that a cabinet is vented, venting should be from the bottom of the cabinet and the exhaust duct and joints must be as fire resistant as the cabinet. For more information, consult with EHS.
- In cabinets that are not vented, ensure safety caps (bungs) are in place over ventilation ports so as to protect the contents from an external fire.

6.4.2 Acid and corrosive storage cabinets

- Cabinets dedicated for acid or corrosives storage must be completely lined with corrosion-resistant materials and include corrosion-resistant hardware.
- It is recommended that acid and corrosive storage cabinets be located below the fume hood and vented in order to prevent the buildup of corrosive vapours, which can degrade the inside of the cabinet.
- Each cabinet should have a spill containment reservoir at the bottom or secondary containers for chemicals stored on each shelf.

6.4.3 Fume hoods

Fume hoods should not be used for long-term chemical storage. Fume hoods which have been designated as temporary chemical storage areas must be labelled “For Storage Only”.

6.4.4 Refrigerators, cold rooms and freezers

Ordinary (domestic) refrigerators and freezers are not designed for chemical use due to the presence of hot surfaces (e.g., light bulbs), possibly sparking switches/thermostats, drains designed for water collection, and potential ignition sources from the motor. Consequently, they are particularly incompatible with flammable materials.

6.4.4.1 Refrigerators for flammable materials

Refrigerators designed for flammable materials have magnetic door seals (to avoid pressure build-up), and the absence of sparks or hot surfaces inside. The motor and motor controls located outside the storage space may generate sparks. This equipment is suitable for use in an ordinary laboratory, but not for use in a hazardous location[1].

Explosion proof refrigerators provide a safe spark-free interior and can be used in a hazardous environment as the motor and motor controls are completely enclosed in housing that has been constructed to safely contain a flash or explosion should flammable gases or vapours penetrate the housing.

6.4.4.2 Cold storage

- Do not store flammable liquids unless the equipment is approved as outlined above.

[1] Hazardous locations are areas where fire or explosion hazards may exist due to, for example, flammable gases, flammable liquid-produced vapours, or combustible dusts present in the air in quantities sufficient to produce explosive or ignitable mixtures.

- Refrigerators, cold rooms and freezers used for chemical storage must never be used to store food. Signage stating “NO FOOD – LAB CHEMICAL STORAGE ONLY” is advised.
- All containers must be closed, stable and adequately labelled. If the cold storage is a shared storage space, the label must also identify the contents’ owner and laboratory.
- Secondary containment, such as plastic trays, is highly recommended for all containers. The trays contain spills and leaks and also facilitate organization and labelling.
- If vapours are a problem in the cold storage, a tray of activated charcoal pellets may be placed on a lower shelf of the cold storage unit.

7. SPECIFIC CHEMICAL HAZARDS AND SEGREGATION

The following sections describe the characteristics of the most common hazard classes and corresponding basic storage guidelines. Note that many chemicals fall into multiple hazard classes. Consequently, it may be necessary to consult several sections to determine how to store a chemical safely. Furthermore, some complex substances may not fit easily into any category, in which case it becomes necessary to consult various other resources (e.g., SDS, literature, your Supervisor, EHS) in order to determine safe storage conditions.

7.1 FLAMMABLES AND COMBUSTIBLES

These substances present a serious fire and explosion hazard if stored incorrectly in the laboratory. The BC Fire Code (2012) classifies a liquid as flammable or combustible according to its flash point, the lowest temperature at which the liquid has sufficient vapour pressure to form an ignitable mixture with air near the surface of the liquid. Classification of flammable and combustible liquids is shown below, with corresponding examples typical to SFU:

BC Fire Code classification	**Flash point**	**Examples**
Flammable or Class I liquids	f.p. < 38 °C	Acetone, diethyl ether, ethanol, hexane, methanol, tetrahydrofuran, toluene, xylene
Combustible or Class II/III liquids	38 °C ≤ f.p. < 93 °C	Acetic acid (glacial), dimethyl sulfoxide, formalin solution, phenol

The BC Fire Code limits the quantity of flammable and combustible liquids in the open laboratory. At SFU, the maximum volume of flammable or combustible liquids permitted in the open laboratory is 25 L. Larger volumes must be stored in an approved flammable storage cabinet, up to a maximum of 500 L per fire compartment (i.e., a laboratory or a shared laboratory).

The WHMIS hazard classes, pictogram and examples for flammables are the following:

Hazard class	**Pictogram**	**Examples**
Flammable gases – see Compressed gases		

Flammable aerosols; Flammable liquids		Acetone, acetic acid (glacial), diethyl ether, ethanol, hexane, methanol, tetrahydrofuran, toluene, xylene
Flammable solids		Magnesium, phosphorus

General requirements for storage of flammables and combustibles:

- Keep flammable and combustible materials away from any ignition sources: heat, flames, sparks, hot surfaces and direct sunlight.
- Keep flammable and combustible materials away from strong oxidizing agents, such as nitric or chromic acid, permanganates, chlorates, perchlorates and peroxides.
- Containers of flammable and combustible liquids must not exceed a capacity of 5 L.
- Ensure an appropriate fire extinguisher is readily available in the laboratory and that laboratory occupants are trained to use it.
- Flammable cabinets are used preferentially for flammable liquids and if space allows, for combustible liquids. See Flammable storage cabinets for additional information.
- Refrigerators and freezers used for storing flammable or combustible liquids must be “Lab safe” or rated for flammable material storage. See Refrigerators, cold rooms and freezers for more information.
- For information about storage of flammable gases, see Compressed gases.

7.2 CORROSIVES

Corrosive substances cause destruction of human tissue at the site of contact and can be solids, liquids or gases. Corrosive substances also damage metals. The WHMIS hazard classes, pictograms and examples of corrosives are the following:

Hazard class	**Pictogram**	**Examples**
Corrosive to metals		Hydrochloric acid, nitric acid, sulfuric acid, sodium hydroxide, ammonium hydroxide
Skin corrosion/irritation	 	Acetic acid, chromic acid, formic acid, hydrochloric acid, nitric acid, phenol, diethylamine, piperidine, sodium hydroxide Benzoic acid, citric acid, maleic acid, tri-sodium phosphate

Serious eye damage/eye irritation		Benzoic acid, formic acid, hydrochloric acid, lithium hydroxide Citric acid, maleic acid, triethanolamine
Specific target organ toxicity, single exposure; Respiratory tract irritation		Citric acid, maleic acid, tri-sodium phosphate, ammonium hydroxide

They can be divided into several major classes to facilitate segregation, as shown below:

Type of corrosives	**Examples**	**Precautions**
Organic acids	Acetic acid, citric acid, formic acid, maleic acid, propionic acid, benzoic acid	Segregate from bases, inorganic acids, water reactive metals
Inorganic oxidizing acids	Chromic acid, nitric acid, perchloric acid*, concentrated sulfuric acid *See Explosive and potentially explosive chemicals	Segregate from bases, organic acids, water reactive metals, flammables and combustibles Concentrated sulfuric and nitric acid should be stored each in its own secondary containment Perchloric acid is only available in small quantities from Science Stores
Inorganic non-oxidizing acids	Hydrochloric acid, hydrofluoric acid, phosphoric acid, sulfuric acid	Segregate from bases, organic acids and oxidizing acids
Organic bases	Diethylamine, piperidine, triethanolamine, benzylamine, benzyltrimethylammonium hydroxide	Segregate from acids, inorganic bases
Inorganic bases	Ammonium hydroxide, potassium hydroxide, sodium hydroxide, tri-sodium phosphate, lithium hydroxide	Segregate from acids, organic bases

General requirements for storage of corrosive substances:

- If storage space permits, acids and bases should be stored in separate cabinets, but can be stored together when segregation is ensured with secondary containment bins.

- Segregate inorganic from organic chemicals, as a general rule of thumb. For chemicals containing both organic and inorganic species, check recommended storage conditions on the SDS and/or in literature.
- Segregate acids from chemicals that could generate toxic gases upon contact with acids (e.g., sodium cyanide and iron sulfide).
- Nitric acid is a strong oxidizer and must be stored separately from incompatibles: flammables, bases, hydrogen sulfide, organic materials, metals and metal compounds.
- Hydrofluoric acid attacks glass and should be stored in tightly closed polyethylene, Teflon, neoprene or nitrile containers. For long-term storage, check permeation ratings for chosen container material. For more information, refer to the Hydrofluoric acid safe handling procedure.
- Segregate acids from water reactive metals such as sodium, potassium and magnesium.
- Do not store corrosives on metal shelves.
- Use corrosion resistant bins (e.g., polypropylene) as secondary containment for spills, leaks, drips or weeping.
- Cabinets used for corrosives storage should be made of corrosion resistant materials and vented. See Acid and corrosive storage cabinets for more information.

7.3 TOXICS

Toxic chemicals may cause injury or death due to overexposure. The WHMIS hazard classes, pictograms and examples include the following:

Hazard class	Pictogram	Examples
Acute Toxicity, oral/dermal/inhalation	 	Acrylamide, ammonia, aniline, hydrogen fluoride, hydrogen sulfide, 2-mercaptoethanol, mercury, phenol, sodium cyanide Lead sulfate, cadmium carbonate, manganese oxide
Carcinogenicity; Germ cell mutagenicity; Reproductive toxicity; Sensitization, respiratory; Specific target organ toxicity, single exposure/repeated exposure		Acrylamide, aniline, lead sulfate, 2-mercaptoethanol, mercury, phenol, potassium chromate, sodium cyanide, toluene, vinyl bromide

General requirements for storage of toxic substances:

- Non-volatile toxic chemicals may be stored in a normal cabinet, separate from incompatibles.
- Volatile toxic chemicals should be stored in a ventilated cabinet.
- Ensure containers are tightly sealed to minimize exposure to personnel and contamination of other chemicals.
- Toxic chemicals that are acid sensitive, such as cyanides and sulfides, must be stored in a separate location from acids and protected from contact.

- Severe poisons should be stored in a dedicated cabinet.
- Controlled substances have additional precautions for secure storage. Contact EHS for assistance.

7.4 OXIDIZERS

Oxidizers will readily initiate and promote the combustion of flammable or combustible materials. They must be kept away from flammable and combustible liquids, greases and other organic compounds. The WHMIS hazard classes, categories, pictogram and examples for oxidizers are the following:

Hazard class	Pictogram	Examples
Oxidizing gases – See Compressed gases		
Oxidizing liquids; Oxidizing solids		Ammonium persulfate, nitric acid, potassium permanganate, chlorates, chlorites, dichromates, nitrates, nitrites, perchlorates, peroxides

General requirements for storage of oxidizers:

- Store in a cool, dry place. Some may require refrigeration – consult the SDS.
- Segregate from flammable and combustible materials, including paper and cardboard.
- Store separately from reducing agents (e.g., zinc, alkaline metals, formic acid).

7.5 WATER-REACTIVES AND PYROPHORICS

Some chemicals violently react with water, and may generate toxic, flammable or corrosive gases. Heat generated from the reaction can ignite flammable by-products (e.g., hydrogen gas) resulting in an explosion. The WHMIS hazard class, pictogram and examples of water-reactives are the following (Note: Many water-reactives are also pyrophoric):

Hazard class	Pictogram	Examples
Substances and mixtures which, in contact with water, emit flammable gases		Acetyl chloride, alkali metals (sodium, lithium, potassium), aluminum borohydride, aluminum chloride anhydrous, chlorosulfonic acid, diborane, diethyl zinc, Grignard reagents (RMgX*), lithium aluminum hydride, silanes, thionyl chloride *R = alkyl; X = halogen

Pyrophoric substances will ignite spontaneously upon contact with air. The WHMIS hazard class, pictogram and examples of pyrophorics are the following:

Hazard class	Pictogram	Examples
Pyrophoric gases – see Compressed gases		

Pyrophoric liquids; Pyrophoric solids		Alkali metals (sodium, lithium, potassium); Grignard reagents (RMgX*); metal alkyls and aryls (tert-butyl lithium); metal carbonyls (lithium carbonyl); metal powders (aluminum, cobalt, iron, zinc); metal hydrides (potassium hydride, sodium hydride); nonmetal hydrides (arsine, phosphine); nonmetal alkyls (R_3B, R_3P* tributyl phosphine); phosphorus (white); silanes *R = alkyl; X = halogen

General requirements for storage of water-reactives and pyrophorics:

- Store in a cool, dry place, away from extremes of temperature and humidity.
- Keep water-reactives away from potential contact with water: segregate from aqueous solutions, do not locate them under a sink and avoid storing them in a sprinklered area and/or protect containers with a waterproof enclosure.
- Keep pyrophorics away from flammables; do not store in a flammable storage cabinet.
- Store all materials in the container provided by the manufacturer, ensuring the integrity of that container is maintained and that sufficient protective solvent, oil or inert gas remains in the container while material is stored.
- Never return excess chemicals to their original, manufacture supplied container. Small amounts of impurities introduced to the container may cause a fire or explosion.
- Consider the use of drying agents and a desiccator and/or an inert gas-filled desiccator or glove box if appropriate.

7.6 COMPRESSED GASES

Compressed gases all have a common hazard, which is the large amount of energy stored in the cylinder. The stored energy presents a physical hazard if it is suddenly released if the cylinder is dropped or knocked over. If gases exhibit other hazards, such as being flammable, toxic or oxidizing, additional precautions are required. The WHMIS hazard classes, pictograms and examples for compressed gases are the following:

Hazard class	**Pictogram**	**Examples**	**Precautions**
Gases under pressure		Any compressed gas in a cylinder	See general requirements below for all compressed gases.
Simple asphyxiants	No pictogram	Argon, helium, nitrogen	Keep in cool, dry area. May be stored together with flammable gases OR with oxidizing gases.

Corrosive gases		Ammonia, hydrogen chloride, hydrogen fluoride	Keep in continuously mechanically ventilated cabinet. Lecture size cylinders may be kept in fume hood.
Flammable gases		Acetylene, hydrogen and other gases mixed with hydrogen, methane, propane	Keep in cool, dry area, away from oxidizers.
Oxidizing gases		Chlorine, oxygen	Keep in cool, dry area away from flammables, combustibles (including wood, paper, packing materials), oil and grease.
Pyrophoric gases		Silanes, phosphines, arsines	Keep in continuously mechanically ventilated cabinet. Lecture size cylinders may be kept in fume hood.
Toxic gases		Ammonia, carbon monoxide, chlorine, hydrogen sulfide	Keep in continuously mechanically ventilated cabinet.

Cylinders are considered “in use” when they are connected to a gas delivery system (i.e., connected through a regulator or connected to a manifold used to deliver gas) designed and tested by a qualified person.

General requirements for storage of compressed gases:

- Limit the quantity of compressed gas cylinders in a laboratory to what is needed for normal operation (i.e., on a weekly basis), since regular delivery can be arranged. Note: The gas cylinder supplier delivers twice a week to the Burnaby campus. Any cylinders not required for normal operation must be placed in designated cylinder storage areas.
- Store compressed gas cylinders in a cool, dry area, and away from incompatible materials, sparks, flames, or excessive heat.
- Protect cylinders from sources of potential physical damage, electrical contact or corrosion (e.g., moisture, salt, acids or chemical fumes).
- Segregate gas cylinders according to gas type.
- Identify empty gas cylinders with an “EMPTY” tag and keep separate from full cylinders.
- Secure cylinders in an upright position, attached to a wall or within a cylinder storage rack. Each cylinder must be restrained by 2 chains: one placed at one third from the top of the cylinder and the other placed at one third from the bottom. Polypropylene and other synthetic plastic straps are not recommended for securing cylinders as they will melt in a fire.
- Lecture sized cylinders are to be stored upright and secured in a wall bracket, cylinder rack, approved stand or cabinet inside a fume hood.
- Bench clamps are not recommended as they are not seismically secure.

- Keep valve protection cap in place (for cylinders designed to accept a cap) when cylinder is not in use and anytime the cylinder is being moved.
- Do not leave a regulator on an unused cylinder for an extended period of time.
- Never store cylinders in any exit or corridor providing access to exits, under any fire escape, outside exit stairs, passage or ramp; or within 1 m of any exit or electrical panel.
- Indoor areas where large amounts of inert gas cylinders are stored may need to be continuously monitored for oxygen levels. Contact EHS for assistance to determine if monitoring is needed in your area.
- When ordering, choose refillable cylinders whenever possible.

Specific requirements for indoor storage of flammable gases:

- Indoor storage of flammable gas is limited by the BC Fire Code depending on the type of gas. Contact EHS for assistance if storing more than one cylinder of flammable gas.
- Cylinders containing flammable gases should be stored at least 6.1 m (20 ft.) away from all flammable, combustible or incompatible substances, such as oxygen or other oxidizers.
- Never lay an acetylene cylinder on its side.
- Liquefied Petroleum Gases (LPGs), for example propane, must not be stored indoors. If indoor laboratory use of LPGs is needed, contact EHS for a risk assessment.
- Order dilute gases to reduce the hazard where possible and appropriate.

Specific requirements for indoor storage of toxic or corrosive gases:

- Toxic or corrosive gases must be located in a ventilated cabinet or room, equipped with relevant continuous monitoring and alarm equipment.
- Gas detectors and monitors must be calibrated and maintained as per the manufacturer’s instructions and records kept of the maintenance.
- Order dilute gases to reduce the hazard where possible and appropriate.

Specific requirements for indoor storage of pyrophoric gases:

- Cylinders of pyrophoric gases greater than lecture bottle size shall be kept in a continuously mechanically ventilated gas cabinet equipped with sprinklers.
- Lecture sized cylinders of pyrophoric gases shall be kept in a continuously mechanically ventilated enclosure, such as a fume hood or gas cabinet.

7.7 CRYOGENS AND DRY ICE

Cryogens are materials at extremely cold temperatures, with boiling points below -150˚C (123 K). Cryogens present a burn hazard from their extreme cold, an asphyxiation hazard from potential oxygen displacement, and an explosion hazard from pressure buildup in containers.

Hazard class	Category	Pictogram	Examples
Gases under pressure	Refrigerated liquefied gas		Liquid helium, b.p. -269 ˚C Liquid nitrogen, b.p. -196˚C Liquid argon, b.p. -186 ˚C

Although not a cryogen, solid carbon dioxide or dry ice also presents similar hazards to cryogens as it sublimates from a solid to a gas at -78 ˚C. Furthermore, while not very toxic, buildup of carbon dioxide in a confined space can lead to unsafe concentrations of CO_2.

General requirements for storage of cryogens and dry ice:

- Store cryogens only in approved storage vessels (e.g., Dewars) that are vacuum-jacketed and equipped with insulation, pressure-relief valves and rupture devices.
- Dewar flasks can collapse from thermal or mechanical shock. Ensure Dewar flasks are shielded with fiber tape or enclosed in a metal container to reduce the risk of flying glass in the event the Dewar flask fails.
- Store all containers with cryogens or dry ice in well-ventilated areas.
- Liquid nitrogen and liquid helium are capable of liquefying oxygen from the air. This form of oxygen enrichment can become a fire or explosion hazard. Therefore, store all cryogenic liquids away from combustible material and do not leave containers uncovered for long periods of time. Use a loose fitting stopper or lid.
- Store dry ice in Styrofoam boxes or covered but unsealed insulated containers.
- Cold rooms are not well ventilated and can quickly become an asphyxiation hazard when cryogens are used in them. Cryogens should not be stored in cold rooms.

7.8 ETHERS AND OTHER PEROXIDE-FORMING CHEMICALS

Certain common laboratory chemicals form peroxides on exposure to oxygen in the air. Over time, some compounds have the potential to build up dangerous levels of peroxides (Class A compounds), while others form comparatively low concentrations of peroxides, which becomes dangerous only when concentrated by evaporation or distillation (Class B compounds). A related group of compounds (Class C) includes monomers that in the presence of peroxides can violently autopolymerize. See the table below for examples:

Type	Examples	Precautions
Class A: chemicals that form explosive levels of peroxides during storage.	Butadiene[a], chlorobutadiene (chloroprene), divinyl acetylene, isopropyl ether, potassium metal, sodium amide, tetrafluoroethylene, vinylidene chloride	Suggested safe storage period: if unopened from manufacturer, up to 18 months or stamped expiry date, whichever comes first. Test for peroxides after

	[a] *When stored as a liquid monomer, can form explosive peroxides without concentration.*	opening and every 3 months. Store under nitrogen if possible.
Class B: these chemicals are a peroxide hazard on concentration (distillation/ evaporation).	Acetal, cumene, cyclohexanol, dicyclopentadiene, diethylene glycol, dimethyl ether (diglyme), diethyl ether, dioxane (p-dioxane), ethylene glycol, dimethyl ether (glyme), furan, methyl-isobutyl ketone, tetrahydrofuran, vinyl ethers	Suggested safe storage period: if unopened from manufacturer, up to 18 months or stamped expiry date, whichever comes first. Test for peroxides after opening, before use, then within 12 months. A test for peroxide should be performed if concentration is intended or suspected.
Class C: unsaturated monomers that may autopolymerize as a result of peroxide accumulation if inhibitors have been removed or depleted.	Acrylic acid, butadiene[b], chlorotrifluoroethylene, methyl methacrylate, styrene, vinyl acetate, vinyl pyridine [b] *When stored as a liquid monomer, can form explosive peroxides without concentration. When stored as a gas, peroxide accumulation can cause violent autopolymerization.*	Suggested safe storage period: if unopened from manufacturer, up to 18 months or stamped expiry date, whichever comes first. For compounds with inhibitors, test for peroxides after opening then within 12 months. For compounds without inhibitors, do not store for longer than 24 hours after opening.

General requirements for storage of ethers and peroxide formers:

- Store in airtight containers in a dark, cool and dry place.
- Avoid glass containers with metal screw-cap lids or glass stoppers for extended storage. Use polyethylene containers, screw caps or stoppers.
- Keep inventory of peroxide formers to an absolute minimum.
- Label containers with a peroxide forming compound label and record the date of receipt, opening, and expiry.
- Periodically test for the presence of peroxides as per the SFU guideline and record testing on container label. A free peroxide test kit is available from Science Stores.
- Certain peroxide-formers (such as Class A above) should be stored under inert gas, if possible.
- Do not keep old samples of organic compounds of unknown origin or history, or those prone to peroxidation if contaminated.

7.9 EXPLOSIVE AND POTENTIALLY EXPLOSIVE CHEMICALS

Explosive chemicals have high potential energy and may detonate, decompose or explode under mild conditions, which can lead to death, serious injury or severe property damage. Heat, shock,

friction or even static electricity can initiate explosions of these chemicals. Included in this category are chemicals that may become explosive if they are handled incorrectly. See the table below for the WHMIS hazard classes, pictograms and examples of explosive or potentially explosive chemicals:

Hazard class	Pictogram	Examples
Self-reactive substances and mixtures; Organic peroxides		Tert-butyl perbenzoate, copper acetylide, cumene hydroperoxide, diazomethane, propiolic acid, 2-nitro-toluidine, acetylenic compounds, azides, peroxides, perchlorate salts, nitrates, perchloric acid, wetted picric acid (> 10% water by wt)

General requirements for storage of explosive and potentially explosive chemicals:

- Identify all explosive and potentially explosive chemicals in your laboratory, and designate an area for their storage and use. Inspect these areas regularly to ensure the correct storage conditions are being maintained (e.g., correct moisture content, under inert gas).
- Never return unused material to the original container provided by the manufacturer. Small amounts of impurities introduced to the container may cause a fire or explosion.
- Keep away from all ignition sources: open flames, hot surfaces, direct sunlight and sparks.
- Perchloric acid storage is not permitted in the laboratory. Researchers must obtain the bottle of perchloric acid from Science Stores, take only what is needed for their experiment and return the bottle to Science Stores the same day. See the Perchloric acid safe handling procedure for more information.
- Solid picric acid must be stored with at least 10% moisture content and be regularly inspected to ensure this level of moisture is maintained.
- For additional information about explosive and potentially explosive compounds, see the Energetic Materials Guide.

7.10 HAZARDOUS WASTE

Hazardous chemical waste is picked up by an external contractor. Requests for pick up from a laboratory can be made at http://hazmatwaste.its.sfu.ca.

Hazardous waste should only be stored for the short-term, until the next available waste removal date, and should be kept at a minimum in laboratories and other work areas. Ensure waste is picked up frequently so it does not accumulate.

General requirements for short-term storage of hazardous waste:

- Ensure all waste is labelled. Standard SFU waste labels can be found at Science Stores or by contacting EHS.
- Solvent waste should be segregated into separate halogenated, non-halogenated, and waste oil containers. Use the provided 5 L white/translucent containers and fill only to the “max fill line”.
- Other solid and liquid chemical waste can be stored in appropriate, and properly labelled containers.

- Collect and store waste according to compatibility and place in secondary containment bins when practical while awaiting pickup.
- Allow sufficient head space for waste containers storing aqueous waste, and fill to 75% of the total container volume and use self-venting caps where appropriate.
- Chemical waste containers awaiting pickup may be kept in an appropriate location such as a designated fume hood, flammable storage cabinet or acid cabinet, depending on the nature of the waste.

8. REFERENCES

B.C. Occupational Health and Safety Regulation www.worksafebc.com

B.C. Fire Code, 2012

NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals, 2015

Canadian Centre for Occupational Health and Safety www.ccohs.ca

Chemical Safety Guide, National Institutes of Health, 2015

Compressed Gas Safety Manual, Concordia University, 2016

Prudent Practices in the Laboratory: Handling and Management of Chemicals, National Research Council, 2011

Safe Storage of Hazardous Chemicals in Stockrooms, Workshops and Laboratories, University of Cambridge, 2017

Safe Storage of Hazardous Chemicals, University of California Berkeley, 2001

Chemical Catalog Reference Manual, Flinn Scientific, 2010

APPENDIX A – QUICK GUIDE TO CHEMICAL STORAGE GROUPS

As proposed by the Flinn Scientific Chemical Catalog Reference Manual, a possible solution to chemical storage in the laboratory is separating chemicals into organic and inorganic families, and then further dividing into related and compatible families. The next section shows each numbered family group (as identified in the following table) situated accordingly in a schematic representation of a chemical cabinet or shelving unit.

Inorganic storage groups	**Organic storage groups**
1. Metals, hydrides 2. Acetates, halides, halogens, iodides, oxalates, phthalates, oleates, sulfates, sulfites, thiosulfates, phosphates, halogens 3. Amides, nitrates (except ammonium nitrate), nitrites, azides 4. Hydroxides, oxides, silicates, carbonates, carbon 5. Sulfides, selenides, phosphides, carbides, nitrides 6. Bromates, chlorates, chlorites, hypochlorites, iodates, perchlorates, perchloric acid, peroxides, hydrogen peroxide 7. Arsenates, cyanides, cyanates 8. Borates, chromates, manganates, permanganates, molybdates, vanadates 9. Acids (except nitric – isolated and stored by itself) 10. Sulfur, phosphorus, arsenic, phosphorus pentoxide 11. Inorganic miscellaneous	1. Acids, amino acids, anhydrides, peracids 2. Alcohols, glycols, sugars, amines, amides, imines, imides 3. Hydrocarbons, esters, aldehydes, oils 4. Ethers, ketones, ketenes, halogenated hydrocarbons, ethylene oxide 5. Epoxy compounds, isocyanates 6. Peroxides, hydroperoxides, azides 7. Sulfides, polysulfides, sulfoxides, nitriles 8. Phenols, cresols 9. Dyes, stains, indicators 10. Organic miscellaneous

SUGGESTED SHELF STORAGE PATTERN – INORGANICS

Inorganic cabinet type 1 (preferably vented) – for Acids

Inorganic #9 – acids, except nitric; store separate from other inorganic chemicals.

Store nitric acid away from other acids unless the acid cabinet provides a separate compartment for nitric acid.

Inorganic cabinet type 2

Bottom → top

Inorganic #10 – sulfur, arsenic, phosphorus, phosphorus pentoxide

Inorganic #2 – halides, sulfates, sulfites, thiosulfates, phosphates, halogens, acetates, oxalates, phthalates, oleates

Inorganic #3 – amides, nitrates, (not ammonium nitrate), nitrites, azides; store ammonium nitrate away from all other substances (ISOLATE IT)

Bottom → top

Inorganic #1 – metals and hydrides – store away from water; store flammables in a flammables cabinet

Inorganic #4 – hydroxides, oxides, silicates, carbonates, carbon

Inorganic cabinet type 3

Bottom → top

Inorganic #7 – arsenates, cyanides, cyanates – store away from water

Inorganic #5 – sulfides, selenides, phosphides, carbides, nitrides

Inorganic #8 – borates, chromates, manganates, permanganates, molybdates, vanadates

Inorganic #6 – chlorates, bromates, iodates, chlorites, hypochlorites, perchlorates, perchloric acid, peroxides, hydrogen peroxide

Other inorganics – ONLY items that do not fit in another category AND can be stored together (based on risk assessment)

Bottom → top

SUGGESTED SHELF STORAGE PATTERN – ORGANICS

Organic cabinet type 1 (non-vented) – for Flammables

Bottom → top

- Organic #2 – alcohols, glycols, sugars, amines, amides, imines, imides
- Organic #3 – hydrocarbons, esters, aldehydes, oils
- Organic #4 – ethers, ketones, ketenes, halogenated hydrocarbons, ethylene oxide
- Organic #9 – alcohol based indicators

Bottom → top

Organic cabinet type 2

Bottom → top

- Organic #2 – alcohols, glycols, sugars, amines, amides, imines, imides – store flammables in a flammables cabinet
- Organic #3 – hydrocarbons, oils, esters, aldehydes – store flammables in a flammables cabinet
- Organic #4 – esters, ketones, ketenes, halogenated hydrocarbons, ethylene oxide – store flammables in a flammables cabinet
- Organic #5 – epoxy compounds, isocyanates
- Organic #7 – sulfides, polysulfides, sulfoxides, nitriles

Bottom → top

Organic cabinet type 3

Bottom → top

Organic #8 – phenol, cresols

Organic #6 – peroxides, azides, hydroperoxides

Organic #1 – acids, amino acids, anhydrides, peracids – store certain organic acids in an acid cabinet

Organic #9 – dyes, stains, indicators – store alcohol-based solutions in a flammables cabinet

Other organics – ONLY items that do not fit in another category AND can be stored together (based on risk assessment)

Bottom → top