CHEMICAL HANDLING IN THE LABORATORY

Transporting chemicals

When transporting chemicals, the following practices should be followed to protect people and the environment, and minimize the potential for spills:

- All chemicals being transported should be placed into secondary containers. If the original container fails, the secondary container can hold the contents of the chemical being transported and prevent chemical spills in a public area (e.g. in the hallway).
- If a single bottle needs to be transported, a bottle carrier is an ideal type of secondary container. If using a container that is not specialized for carrying chemicals (e.g. bucket, pail), packing material that is compatible with the chemical(s) should be used to prevent bottles from tipping over or breaking during transport.

- To carry more than one chemical, a cart with lipped surfaces or a tray should be used. Ensure that the size of the tray will contain all of the chemicals being transported and that the chemicals are compatible with each other and the material of the tray.
- If possible, do not use passenger elevators when transporting chemicals; only freight elevators should be used. If it is necessary to use a passenger elevator, use should be restricted to low-use times (e.g. early morning or late afternoon). If this is not possible, warn passengers and/or prohibit them from riding on the same elevator.
- If hazardous materials need to be transported or shipped off campus, specific procedures, training and other legal requirements **must** be followed. Contact the Office of Environmental Health and Safety for more information.

Containers

- Containers must be compatible with and resistant to their contents. For example, hydrofluoric acid must not be stored in glass containers.
- Inspect chemical stocks regularly and dispose of damaged or deteriorated containers.
- Keep containers securely closed when not in use, although some – for example, lithium aluminum hydride, formic acid, nitric acid, and chromic acid – may need to be vented periodically to prevent a potentially explosive build-up of gases.

Chemical Inventory

- A chemical inventory should be established for each laboratory and submitted to the department chair.
- All containers should be labelled with a purchase date, the date the container is opened, and where applicable, an expiry date. Chemicals not stored in original containers should also be dated.
- The chemical inventory should be reviewed at least once a year.
- Proper disposal procedures must be used for chemicals that have expired.

CHEMICAL STORAGE IN THE LABORATORY

These guidelines for proper and safe storage of chemicals should be followed:

- Wherever possible, chemicals should be stored in designated areas in the laboratory which can only be accessed by authorized laboratory personnel.
- **Properly label** all chemical containers in the laboratory.
- Keep **quantities** of chemical substances and container sizes to a **minimum**.
- **Clean** up spills and drips **immediately**.
- Chemicals should be returned to their proper storage area **after each use**.
- The storage of chemicals on bench tops should be kept to a minimum to help prevent clutter and spills, and allow for adequate working space.
- **Do not** store chemicals in fume hoods as the containers can interfere with the airflow, reduce working space, and increase the risk of a spill, fire or explosion.
- **Do not** store chemicals in aisles or on the floor due to the potential for bottles to be knocked over and cause a spill. Containers should not be stored near exits because they could obstruct egress in the event of a fire or explosion.
- **Keep** all chemical containers **closed** when not in use. Ensure caps and lids are securely tightened on containers to prevent leaks and evaporation of contents. **Never** store a container open with a funnel in it.
- **Store** chemicals **away** from ignition sources such as open flames, heat sources or direct sunlight.
- **Do not** store chemicals alphabetically unless they have first been separated into hazard classes. Always segregate and store chemicals according to compatibility and hazard classes. If a chemical has more than one hazard, segregate according to the primary hazard. Always take precautions with respect to the proximity of incompatible chemical substances.
- **Do not** store chemicals, large, awkward, heavy or breakable items above eye level/shoulder height.
- Highly toxic chemicals should be stored in locked storage cabinets. Always keep the quantities of highly toxic chemicals to an absolute minimum.
- **Never** stack bottles on top of each other.
- Store larger containers on lower shelves. Larger bottles should also be stored towards the back and smaller bottles stored up front where they will be visible.
- Chemical bottles should be turned with the **labels facing out** so they can be **easily read**.
- Store chemicals inside cabinets or on **sturdy** shelving that has edge guards to **prevent** containers from falling.

- Shelves should be level, stable, and secured to the wall or another stable surface. Containers **should not protrude** over shelf edges.
- **Store** liquid chemical containers in chemically-resistant **secondary containers** such as trays and tubs that are large enough to hold spills if any bottle breaks.
- Store volatile toxic chemicals in a way that prevents release of vapours (e.g. inside closed secondary containers, ventilated cabinets).
- Store flammable liquids in approved safety containers in flammable storage cabinets. Do not store anything but flammable or combustible liquids in these cabinets.
- Flammable liquids must not be stored in laboratory refrigerators unless the unit is an approved, explosion-proof or laboratory-safe refrigerator.
- Label reactive or unstable chemicals (e.g. ethers) with the date of receipt and the date opened.
- **Inspect** chemicals **regularly** for signs of deterioration and for label integrity.
- Promptly dispose of unwanted chemicals.
- Keep storage areas well lit, properly ventilated, and at a consistent, cool temperature.
- Keep emergency equipment such as fire extinguishers nearby and in good working order.
- Confine chemical storage areas so that leaks or spills are controlled. Prevent chemicals from going down the sink, floor or storm water drains.
- When there are multiple containers of the same chemical, older containers should be stored in front of newer chemicals and the containers with the least amount of chemical should be stored in front of full containers. This will allow older chemicals to get used first and help minimize the number of chemical containers in the storage area.
- **Do not** store acids in flammable liquid storage cabinets. This can result in the degradation of the storage cabinet and the containers inside. Corrosive chemicals should be stored in corrosion resistant cabinets.

CHEMICAL SEGREGATION AND CHEMICAL INCOMPATIBLITIES

- Accidental contact between incompatible chemicals can result in a fire, an explosion, the formation of toxic and/or flammable gases and vapours, or other potential harmful reactions. Each chemical must be evaluated to determine where and how it should be stored.
- Hazardous materials should always be segregated and stored according to their chemical family or hazard classification. **Do not** store chemicals alphabetically unless they are compatible.
- Ideally, each hazard class should be kept in a cabinet or on a shelf segregated from other hazard classes. Incompatible chemicals within the same hazard class should also be separated from one another.

- Many chemicals belong to more than one chemical family or hazard class. In such cases, all storage rules must be strictly observed.
- Everyone in the laboratory must know how the chemicals should be segregated.
- It is recommended to clearly identify where chemicals in each hazard class will be stored by labelling cabinets with signs or hazard class labels.
- At minimum, the following practices should be followed when segregating chemicals:
  - Segregate acids from bases.
  - Segregate most organic acids from mineral acids.
  - Keep oxidizers away from other chemicals, especially flammables or combustibles.
  - Keep corrosives away from substances they may react with and release corrosive, toxic, or flammable vapours.
  - The following tables provide recommended guidelines for segregating incompatible chemicals. These guidelines must be used in conjunction with container labels, MSDSs and manufacturer's recommendations.

Online Resource

The National Oceanic and Atmospheric Administration website has a great online tool called the Chemical Reactivity Worksheet. This free program can be used to find out about the reactivity of substances or mixtures of substances. The program includes a database of reactivity information for more than 5000 common hazardous chemicals. It allows users to virtually "mix" chemicals to find out what dangers could arise from accidental mixing. For additional information and to download the software, go to: http://www.noaa.gov/

Table 3: Chemical Incompatibilities by Hazard Class

	Acids, Inorganic	Acids, Organic	Acids, Oxidizing	Bases (Alkalis)	Oxidizers	Poisons, Inorganic	Poisons, Organic	Solvents, Organic	Water Reactives
Acids, Inorganic		✘		✘		✘	✘	✘	✘
Acids, Organic	✘		✘	✘	✘	✘	✘		✘
Acids, Oxidizing		✘		✘		✘	✘	✘	✘
Bases (Alkalis)	✘	✘	✘				✘	✘	✘
Oxidizers		✘					✘	✘	✘
Poisons, Inorganic	✘	✘	✘				✘	✘	✘
Poisons, Organic	✘	✘	✘	✘	✘	✘			
Solvents, Organic	✘		✘	✘	✘	✘			
Water Reactives	✘	✘	✘	✘	✘	✘			

✘ **= NOT COMPATIBLE – DO NOT STORE TOGETHER**

Source: Berkeley Lab Environmental Health & Safety Division

Table 4: Common Chemical Incompatibles (not a complete list)

Chemical	Incompatible with the following common chemicals
Acetic acid	**Chromic acid, nitric acid, alcohols, ethylene glycol, perchloric acid, peroxides, permanganates**
Acetic anhydride	**Hydroxyl-containing compounds (e.g. ethylene glycol, perchloric acid)**
Acetone	**Bromine, chlorine, nitric acid, sulphuric acid, and hydrogen peroxide**
Acetylene	**Bromine, chlorine, copper, mercury, fluorine, iodine, silver**
Alkali and alkaline metals (e.g. sodium, potassium, lithium, magnesium, calcium, powdered aluminum)	**Carbon dioxide, carbon tetrachloride and other chlorinated hydrocarbons, water, bromine, chlorine, fluorine, iodine**
Aluminum and it Alloys (especially powders)	**Acid or alkaline solutions, ammonium persulphate and water, chlorates, chlorinated compounds, nitrates, organic compounds in nitrate/nitrate salt baths**

Ammonia, anhydrous	**Bromine, chlorine, calcium hypochlorite, hydrofluoric acid, iodine, mercury, and silver**
Ammonium nitrate	**Acids, metal powders, flammable liquids, chlorates, nitrates, sulphur , fine-particulate organic or combustible materials**
Aniline	**Hydrogen peroxide, nitric acid**
Arsenic compounds	**Reducing agents**
Azides	**Acids**
Bromine	**Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, metal powders, sodium carbide, turpentine**
Calcium oxide	**Water**
Carbon, activated	**Calcium hypochlorite, all oxidizing agents**
Carbon tetrachloride	**Alkali and alkaline metals (e.g. sodium)**
Chlorates or Perchlorates	**Acids, aluminum, ammonium salts, cyanides, phosphorus, metal powders, oxidizable organics or other combustibles, sugar, sulphides, sulphur**
Chlorine	**Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, metal powders, sodium carbide, turpentine**
Chlorine dioxide	**Ammonia, methane, phosphine, hydrogen sulphide**
Chromic acid	**Acetic acid, naphthalene, camphor, alcohol, glycerine, turpentine and other flammable liquids**
Copper	**Acetylene, hydrogen peroxide**
Cumene Hydroperoxide	**Acids**
Cyanides	**Acids**
Flammable liquids	**Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, bromine, chlorine, fluorine, iodine**
Fluorine	**Store separately**
Hydrazine	**Hydrogen peroxide, nitric acid, oxidizing materials**
Hydrocarbons (butane, propane, benzene, etc)	**Bromine, chlorine, chromic acid, fluorine, hydrogen peroxide, sodium peroxide**
Hydrocyanic acid	**Nitric acid, alkalis**
Hydrofluoric Acid	**Ammonia, aqueous or anyhydrous**
Hydrogen peroxide	**Chromium, copper, iron, metals and metal salts, aniline, flammable liquids, combustibles (solid or liquid), nitromethane, and all other organic material**
Hydrogen sulphide	**Fuming nitric acid, oxidizing gases**
Iodine	**Acetylene, ammonia (anhydrous or aqueous), hydrogen**
Mercury	**Acetylene, alkali metals, ammonia, nitric acid, hydrogen, oxalic acid**
Nitrates	**Combustible materials, esters, phosphorous, sodium acetate,**

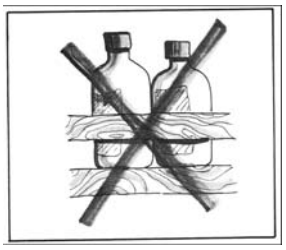
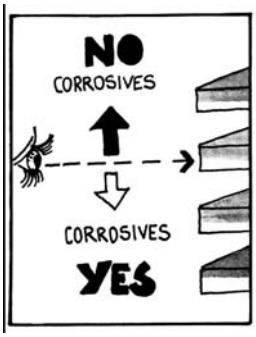
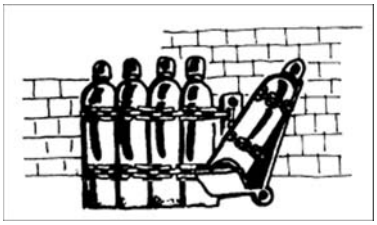
	stannous chloride, water, zinc powder
Nitric acid, concentrated	**Acetic acid, acetone, alcohol, aniline, chromic acid, flammable gases and liquids, hydrocyanic acid, hydrogen sulphide, nitrabtable substances (e.g. copper, brass, heavy metals, organic products (wood, paper))**
Nitrites	**Potassium or sodium cyanide**
Nitroparaffins	**Inorganic bases, amines**
Oxalic Acid	**Silver, mercury and their salts**
Oxygen (liquid or enriched air)	**Flammable gases, liquids, or solids such as acetone, acetylene, grease, hydrogen, oils, phosphorous**
Perchloric Acid	**Acetic anhydride, alcohols, bismuth and its alloys, paper, wood, grease, oils or any organic materials and reducing agents**
Peroxides, organic	**Acid (inorganic or organic). Avoid friction and store cold.**
Phosphorus, white	**Air, oxygen**
Phosphorus pentoxide	**Alcohols, strong bases, water**
Potassium	**Air (moisture and/or oxygen) or water, carbon tetrachloride, carbon dioxide**
Potassium chlorate	**Sulphuric and other acids**
Potassium perchlorate	**Acids**
Potassium permanganate	**Benzaldehyde, ethylene glycol, glycerol, sulphuric acid**
Selenides	**Reducing agents**
Silver and silver salts	**Acetylene, oxalic acid, tartaric acid, fulminic acid, ammonium compounds**
Sodium	**See Alkali Metals**
Sodium Chlorate	**Acids, ammonium salts, oxidizable materials and sulphur**
Sodium nitrate	**Ammonia compounds, ammonium nitrate, or other ammonium salts**
Sodium peroxide	**Any oxidizable substances, such as ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulphide, glycerol, ethylene glycol, ethyl acetate, methyl acetate, furfural, etc.**
Sulphides	**Acids**
Sulphuric acid	**Chlorates, perchlorates, permanganates, compounds with light metals such as sodium, lithium, and potassium**
Tellurides	**Reducing agents**
Water	**Acetyl chloride, alkaline and akaline metals, their hydrides and oxides, barium peroxide, carbides, chromic acid, phosphorous oxychloride, phosphorous pentachloride, phosphorous pentoxide, sulfuric acid, sulphur trioxide**

Source: Princeton University Laboratory Safety Manual; McGill University Laboratory Safety Manual

Table 5: Storage Requirements for Specific Hazard Classes

CLASS	STORAGE REQUIREMENTS
Flammable and Combustible Liquids 	▪ Keep flammables away from all ignition sources. ▪ Keep containers closed when not in use. ▪ Store separate from other hazard classes, especially oxidizers and toxic chemicals. ▪ Up to 5 L of flammable liquids can be stored in a plastic or glass container; up to 25 L may be stored in a metal container (ULC approved). ▪ The maximum volume of flammable AND combustible liquids permitted in each lab is 300 L, of which only 50 L may be flammable. Quantities beyond this limit **must** be stored in an approved flammable liquid storage cabinet in the lab. ▪ A flammable liquid storage cabinet may contain up to 500 L of flammable AND combustible liquids, of which 250 L may be flammable.  ▪ Do not exceed the permissible storage capacity. ▪ Storage cabinets for containers of flammable liquids are meant to: protect flammable liquids against flash fires, prevent excessive internal temperatures in the presence of fire, and contain spilled flammable liquids to prevent the spread of fire. ▪ Do not store flammable and combustible materials with non-combustible materials. Do not store paper or cardboard or other combustible packaging material in a flammable storage cabinet. ▪ Storage cabinets are not required to be ventilated. If there are ventilation openings in the cabinet, these openings must be sealed with materials providing appropriate fire protection or the cabinet must be vented outdoors using fire protection piping. ▪ Storage cabinets should be properly labelled to indicate that they contain flammables and to keep away from open flames and other sources of ignition. ▪ No combustible material should be permitted in storage rooms. ▪ **Do not** store containers and/or cabinets near exits, elevators, or routes that provide access to emergency equipment (eyewash, fire extinguisher, etc.). ▪ Where static electricity may accumulate and ignite flammable vapours, ground and bond flammable liquid containers. ▪ Where flammables are refrigerated, laboratory-safe flammable material refrigerators or freezers **must** be used to avoid ignition of materials by sparks or static electricity. The refrigerators or freezers must be properly labelled as flammable storage.

Toxic Chemicals  	▪ Segregate toxics from other hazard classes and store in cool, well ventilated areas, away from light and heat. ▪ Containers should be tightly sealed to minimize exposure to personnel and contamination of other chemicals. ▪ The quantity of highly toxic chemicals in the laboratory should be kept to a minimum. ▪ Store according to manufacturer's recommendations, away from incompatible chemicals.
Explosive and Highly Reactive Chemicals 	▪ Store in cool, dry area away from normal work areas, protected from shock, vibration, incompatible chemicals, elevated temperatures, and rapid temperature changes. ▪ Keep away from all ignition sources such as open flames, hot surfaces, direct sunlight, and other heat sources. ▪ For chemicals that may degrade and become potentially explosive, record the opening date and discard date on the container or label. ▪ Store in designated areas. ▪ Be cautious of compounds that must remain moist or wet when stored. ▪ Pay attention to potentially explosive compounds that appear to exhibit the following signs: deterioration, crystalline growth inside or outside the container, and/or discolouration of the chemical. ▪ Keep containers tightly closed. Some dangerously reactive liquids, such as certain organic peroxide products, gradually decompose at room temperature and give off gas. These containers should have vented caps to relieve the normal build-up of gas pressure that could rupture a non-vented container. ▪ Keep vented containers in an upright position. Never stack vented containers on top of each other. ▪ Never transfer materials stored in a vented container into a tightly-sealed, non-vented container.
Water Reactives 	▪ Store in cool, dry area. ▪ Keep away from sources of water. ▪ In case of fire, do not use water. Use a dry chemical extinguisher. ▪ Protect chemicals from sprinkler systems.
Air Reactives (Pyrophorics)	▪ Substances that ignite spontaneously upon contact with air. ▪ Store in a cool, dry place. Prevent contact with air. ▪ Take extreme care to prevent containers from leaking or breaking. ▪ Many chemicals that are air reactives are also water reactives.

Oxidizing Agents 	▪ Store according to manufacturer's recommendations, away from incompatible chemicals. ▪ Segregate oxidizers from flammable and combustible materials. ▪ Segregate oxidizers from reducing agents. ▪ Segregate inorganic oxidizers from organic peroxides. ▪ Store in a cool, dry place. Do not store under sink. ▪ Do not contaminate oxidizers. Do not store oxidizers on wood shelves. A leak could start a fire. 
Corrosive Chemicals 	▪ Segregate acids from bases. Segregate inorganic oxidizing acids (e.g. nitric acid) from organic acids (e.g. acetic acid), flammables, and combustibles. ▪ Segregate acids from chemicals that could generate toxic gases upon contact (e.g. sodium cyanide and iron sulphide). ▪ Segregate acids from water reactive metals such as sodium, potassium and magnesium. ▪ Store corrosives on lower shelves, at least below eye level. ▪ Do not store corrosives on metal shelves as the chemicals can cause corrosion. Store containers in plastic tubs or trays for secondary containment. ▪ Store in cool, dry, well-ventilated area on corrosion-resistant materials. 
Compressed Gases 	▪ Store compressed gas cylinders in a well-ventilated area segregated from flammable and corrosive materials. ▪ Store oxygen and fuel gases separately. Indoors, separate oxygen from fuel gas cylinders by at least 20 feet or separate them with an approved fire wall. ▪ Keep cylinders away from electrical circuits, direct sunlight and ignition sources such as sparks, flames, or hot surfaces. ▪ Limit the quantity of compressed gas cylinders in the laboratory. ▪ Separate flammable gases from oxidizing gases with non-combustible partitions. ▪ Leave the valve cap on the cylinder unless it is in use. ▪ Always chain or securely restrain cylinders in an upright position to prevent them from falling. Secure each cylinder individually.  ▪ If pressure testing is required, indicate on the cylinder when it was pressure-tested. ▪ Label empty cylinders and store them separately from other cylinders.
Cryogenic Materials	▪ Store in well-ventilated area. Secure containers so they will not tip over. ▪ Do not store containers where they can come into contact with moisture.

	▪ Use only approved storage vessels with pressure-relief mechanisms.
Peroxide Forming Chemicals	▪ Identify all peroxide forming chemicals in your laboratory inventory. ▪ Write the opening date and discard date on the containers of chemicals that may degrade or become potentially explosive. ▪ Store in airtight containers in a dark, cool, and dry place. ▪ **Never** store peroxide formers in a freezer because a change from a solid to a liquid can cause detonation. ▪ Inspect peroxide-forming chemicals often for evidence of contamination, degradation or any change from normal physical or chemical characteristics.