Health & Safety Technical Guidelines

HS-TG- 01

Chemicals Safety

Produced by

Health & Safety – Facilities & GS Department

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1 Purpose

The purpose of this document is to protect the health and well-being of all Qatar University (**QU**) staff, students, and visitors, and to prevent damage to property, equipment, facilities, and the environment associated with the usage of chemicals as part of the university's activities.

This document provides guidelines on the application of the requirements and principles of the QU Health & Safety Management System (HSMS) to activities associated with these QU workplaces.

2 Scope

This H & S Technical Guideline applies to all operations and activities associated with QU activities where chemicals are involved, including laboratories, workshops, storage areas and other QU work sites, to enable the effective management of H & S risks within these workplaces.

3 Responsibilities

3.1 Top Management

QU top management shall allocate sufficient resources for the effective implementation of the HSMS, including the application of this H & S Technical Guideline, and ensure that QU employees, students, contractors and visitors are aware of their responsibilities through appropriate regulation, delegation and communication.

The QU Top Management is also accountable for monitoring and reporting H & S performance and appropriate programs and actions to ensure compliance with the QU H & S Policy.

3.2 Other Accountabilities

The QU H & S and the H & S Committee are accountable to the QU Top Management for the implementation of this H & S Technical Guideline.

Vice President (VPs), Deans, Directors, Managers, Head Sections/Units and Project Managers are accountable to the QU Top Management for the application of this H & S Technical Guideline in areas under their supervision.

All QU staff is responsible for performing their duties by complying with the requirements of this H & S Technical Guideline as it applies to their activities and workplaces, observing and obeying safety postings and rules, and promptly reporting all incidents and accidents to their supervisors.

4 Guidelines

4.1 Types of Hazards

Irritants

Irritants are materials that cause inflammation of the body surface with which they come in contact. The inflammation results from concentrations far below those needed to cause corrosion. Common irritants include substances such as:

- ammonia
- alkaline dusts and mists
- hydrogen chloride
- hydrogen fluoride*
- halogens
- ozone
- phosgene*
- nitrogen dioxide
- phosphorus chloride
- arsenic trichloride

* These materials also have other hazardous properties.

Irritants can also cause changes in the mechanics of respiration and lung function. These include:

- sulfur dioxide
- acetic acid
- formaldehyde*
- formic acid
- sulfuric acid
- acroleins
- halogens

* These materials also have other hazardous properties.

Long term exposure to irritants can result in increased mucous secretions and chronic bronchitis.

A primary irritant exerts no systemic toxic action, either because the products formed on the tissue of the respiratory tract are non-toxic or because the irritant action is more severe than any systemic toxic action. Example: hydrogen chloride.

A secondary irritant's effect on mucous membranes is overshadowed by a systemic effect resulting from irritant absorption. These include:

- hydrogen sulfide
- aromatic hydrocarbons

Exposure to a secondary irritant can result in pulmonary edema, hemorrhage and tissue necrosis.

Asphyxiants

Simple Asphyxiants deprive the tissue of oxygen. Simple asphyxiants are inert gases that displace oxygen. These include:

- nitrogen
- nitrous oxide
- carbon dioxide
- helium

Chemical asphyxiants render the body incapable of maintaining an adequate oxygen supply. They are active at very low concentrations (few ppm). These include:

- carbon monoxide
- cyanides

Hepatotoxic Agents

Hepatotoxic agents cause damage to the liver. These include:

- carbon tetrachloride
- tetrachloroethane
- nitrosamines

Nephrotoxic Agents

Nephrotoxic agents damage the kidneys. These include:

- halogenated hydrocarbons
- uranium compounds

Neurotoxic Agents

Neurotoxic agents damage the nervous system. The nervous system is especially sensitive to organometallic compounds and certain sulfide compounds. These include:

- trialkyl tin compounds
- tetraethyl lead
- methyl mercury
- carbon disulfide
- organic phosphorus insecticides
- manganese
- thallium

Some toxic agents act on the blood or hematopoietic system. The blood cells can be directly affected or the bone marrow can be damaged. These include:

- nitrites
- aniline
- toluidine
- nitrobenzene
- benzene

There are toxic agents that produce damage of the pulmonary tissue (lungs) but not by immediate irritant action. Fibrotic changes can be caused by free silica and asbestos. Other dusts can cause a restrictive disease called pneumoconiosis.

Carcinogens

The term carcinogen describes any agent that can initiate or speed the development of malignant or potentially malignant tumors, malignant neoplastic proliferation of cells, or cells that possess such material. A select carcinogen is any substance that meets one of the following criteria:

- It is regulated by the United States Occupational Safety and Health Administration as a carcinogen.
- It is listed under the category, "known to be carcinogens" in the United States National Toxicology Program (NTP).
- It is listed under Group 1, "carcinogenic to humans" by the International Agency for Research on Cancer Monographs (IARC).
- It is listed under Group 2A or 2B by IARC or under the category "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals according to any of the following criteria:
- After inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime, to doses of less than 10 mg/m3.
- After repeated skin applications of 300 mg/kg of body weight per week.
- After oral doses of less than 50 mg/kg of body weight per day.

Reproductive Hazards

Reproductive hazards are chemicals that affect the reproductive capabilities including chromosomal damage (mutagens) and effects on the fetus (teratogens).

A mutagen affects the chromosome chains of exposed cells. The effect is hereditary and becomes part of the genetic pool passed on to future generation.

A teratogen (embryo toxic or fetotoxic agent) is an agent that interferes with the normal embryonic development without damage to the mother or lethal effect on the fetus. Effects are not hereditary.

A sensitizer causes the majority of the exposed population to develop an allergic reaction in normal tissues after repeated exposure to the chemical. The reaction may be as mild as a rash (contact dermatitis) or as serious as anaphylactic shock.

A list of reproductive hazards can be found in Appendix B.

Highly Toxic Chemicals

High toxic compounds have the ability to cause harmful effects which can be local or systemic after a single exposure. Among the most useful parameters for assessing the risk of acute toxicity of a chemical are its LD_{50} and LC_{50} values, the mean lethal dose or lethal concentration causing death in experimental animals. A substance is highly toxic if:

- the oral LD_{50} for albino rats is less than 50 mg/kg
- the topical LD_{50} for albino rabbits is less than 200 mg/kg
- the LC_{50} in albino rats is less than 200 ppm for one hour

The list of highly toxic chemicals is in Appendix C. A chemical's absence from this list does not necessarily mean that it is not highly toxic. Always refer to the chemical's Material Safety Data Sheet (**MSDS**).

Explosive Chemicals

Explosives are solid, liquid, or gaseous chemicals that can cause a sudden, almost instantaneous release of pressure, gas and heat when subjected to shock, pressure or high temperature. Their acquisition, storage, use and disposal are highly regulated and these materials demand the highest safety precautions.

Coordinate with the H & S for proper handling of explosive materials in the laboratory.

Reactive Chemicals

The variety of chemicals commonly present in the laboratory poses the potential for accidental hazardous chemical reactions or explosions. A hazardous reaction occurs when two or more incompatible chemicals combine, resulting in an undesirable or uncontrolled reaction with adverse consequences. Such reactions may result when incompatible chemicals spill by accident, inadvertently mix as chemical waste, or combine unwittingly during experimental procedures.

Hazardous reactions may cause any one or more of the following:

- Heat generation
- Fire
- Explosion
- Formation of toxic vapors
- Formation of flammable gases
- Volatilization of toxic or flammable substances
- Formation of substances of greater toxicity
- Formation of shock or friction sensitive compounds
- Pressurization in closed vessels
- Solubilization of toxic substances
- Dispersal of toxic dusts, mists, particles
- Violent polymerization

A reactive chemical is any solid, liquid or gaseous chemical substances that have the potential to react rapidly to release relatively large amounts of energy and/or dangerous by products (e.g. toxic gases). Some of these chemicals are:

- **Acetylenic Compounds** are explosive in mixtures of 2.5- 80% with air at pressures of two or more atmospheres. Acetylene (C_2H_2) subjected to an electrical discharge or high temperature decomposes with explosive violence. Dry acetylides detonate on receiving the slightest shock.
- **Aluminum Chloride** ($AlCl_3$) is a potential dangerous material because if moisture is present, decomposition can produce hydrogen chloride (HCl) and build up considerable container pressure. When opening a bottle that has been stored for a long time, completely enclose it in a heavy towel.
- **Ammonia** (NH_3) reacts with iodine to produce nitrogen tri-iodide (which is explosive) and with hypochlorite to produce chlorine. Do not mix ammonia-based cleaners with bleach. Mixtures of ammonia and organic halides sometimes react violently when heated under pressure.
- **Aqua Regia** is a mixture of nitric acid and hydrochloric acid and is sometimes used for dissolving noble metals or as glassware cleaner. Try to avoid using aqua regia. If needed, use only what is needed in a laboratory fume hood and destroy it within the hood after use. Do not store it in closed containers; attempts to store aqua regia will most likely rupture the storage container. Upon generation, the nitric acid begins to reduce, with evolution of toxic nitrogen dioxide gas.
- **Bensoyl Peroxide** ($C_6H_5CO_2$) is easily ignited and sensitive to shock. It decomposes spontaneously at temperature above 50^oC but a cab be desensitized by addition of 20% by volume of water.
- **Carbon Disulfide** (CS_2) is highly toxic and highly flammable; when mixed with air, its vapors can ignite by a steam bath or pipe, a hot plate, or a glowing light bulb. Carbon disulfide catches fire spontaneously upon contact with a hot surface at a temperature approximating or exceeding 80 ^oC.
- **Chlorine** (Cl_2) may react violently with hydrogen (H_2) or with hydrocarbons when exposed to sunlight.
- **Diazomethane** (CH_2N_2**)** and related diazo compounds require extreme caution. They are very toxic and the pure forms (gases and liquids) explode readily. Diazald (a precursor to diazomethane) is a high explosive. Solutions in ether are safer and are rendered harmless by drop wise addition of acetic acid.
- **Diethyl**, **Isopropyl and other Ethers** (particularly the branched-chain type) may explode during heating or refluxing due to the presence of peroxides. Ferrous salts or sodium bisulfate can decompose these peroxides and passage over basic active alumina will remove most of the peroxide material. Mark containers with the date received, date opened, and date to be discarded, and discard them before they are out of date.
- **Diethylzinc** $[(C_2H_5)_2Zn$ is a violently pyrophoric (air reactive), water-reactive and light sensitive liquid and is generally sold in mixture with toluene, hexane, or other organic solvents. At concentrations above 1.1 molar, store diethylzinc in an inert atmosphere at or below room temperature. Do not use water for extinguishing fires; use dry powder, soda ash or lime.
- **Dimethyl Sulfoxide** $[(CH_3)SO]$ decomposes violently on contact with wide variety of active halogen compounds. Explosions from contact with active metal hydrides have been reported. Its toxicity is still unknown, buy it penetrates and carries dissolved substances through the skin membrane.
- **Dinitrophenols** $[(NO_2)_2C_6H_3OH]$ such as 2,4-DNP and 2,6-DNP are sensitive to light, heat, friction and shock and should never be allowed to dry out. 2,4-DNP form explosive salts with alkalis and ammonia. Oxidative decomposition can produce nitrogen oxides. At water concentrations less than 15%, DNPs are explosive.

- **Dry ice**, a solid carbon dioxide (CO_2) is not to be kept in a container that is not designed to withstand pressure. Containers of other substances stored over dry ice for extended periods generally absorb carbon dioxide unless sealed with care. When removing such containers from storage and allowing them to come rapidly to room temperature, the CO_2 may develop sufficient pressure to burst the container with explosive violence. On the removal of such containers from storage, loosen the stopper, or wrap the container in towels and keep it behind a shield. Dry ice can produce serious burns. Do not store dry ice in walk-in cold rooms, as this may result in an oxygen deficient atmosphere.
- **Drying Agents-Ascarite** must not mix with phosphorus pentoxide (P_2O_5) because the mixture may explode if warmed with a trace of water. Since organic solvents may extract the cobalt salts used as moisture indicators in some drying agents, the use of these drying agents shall be restricted to gases
- **Ethylene Oxide** (C_2H_4O) can explode when heated in a closed vessel. Carry out experiments using ethylene oxide under pressure behind suitable barricades.
- **Fulminic Acid** (HCNO), metal salts and other compounds that contain the fulminate ion ($C\Xi N^+$-O^-) are highly unstable due to the weak single N-O bond. Fulminates are friction-sensitive primary explosives.
- **Grignard Reagents** (R-Mg-X) are alkyl- or aryl- magnesium halides that are highly reactive with oxygen and carbonyls. They can spontaneously ignite in most air; handle Grignard reagents under inert gases such as argon or nitrogen, or in solvents such as tetrahydrofuran or ethyl ether.
- **Halogenated Compounds** such as chloroform ($CHCl_3$), methylene chloride (CH_2Cl_2), carbon tetrachloride (CCl_4), and other halogenated solvents shall not be dried with sodium, potassium, or other active metals; violent explosions can result.
- **Hydrogen Peroxide** (H_2O_2) stronger than three percent (3%) can be dangerous; in contact with the skin, it may cause severe burns. Thirty percent H_2O_2 may decompose violently if contaminated with iron, copper, chromium, other metals or salts. Stirring bars may inadvertently bring metal into a reaction, so use with caution.
- **Liquid-Nitrogen Storage Cooled Traps**, when opened into the atmosphere, it rapidly condenses liquid air. With coolant removal, a pressure buildup may occur and be sufficient to shatter glass equipment. Only cool sealed or evacuated equipment with liquid nitrogen.
- **Liquid Nitrogen Storage Dewars** are common for cryopreservation of samples. Cryopreservation vials stored in the liquid phase of liquid nitrogen can rupture upon warming if liquid nitrogen has infiltrated them, as the liquid nitrogen expands more than 600 times during evaporation. Store vials in the gaseous state go above the liquid nitrogen to avoid infiltration.
- **Lithium Aluminum Hydride** ($LiALH_4$) shall not be used to dry methyl ethers or tetrahydrofuran. The products of its reaction with CO_2 can be explosive. Do not use carbon dioxide or bicarbonate extinguishers against $LiAlH_4$ fires; use sand or a class D extinguisher.
- **Nitric Acid** (HNO_3) is a powerful oxidizing agent that ignites on contact or reacts explosively with a variety of organic substances including acetic anhydride, acetone, acetonitrile, many alcohols, benzene, DMSO, and methylene chloride. Do not store nitric acid with combustible organic acids such as acetic acid or formic acid. Nitric acid can also react violently with many inorganic substances including bases, reducing agents, alkali metals, copper, phosphorus, and ammonia.
- **Nitrocellulose** [($C_6H_7O_{11}N_3$)n] in dry, unstabilized form becomes explosive when heated or subjected to sudden shock. Store moist, away from heat sources and sunlight, and segregated from other materials. Nitrocellulose in membrane filters with polyester backing and mixed cellulose ester (MCE) filters is more stable, but can still

spontaneously combust when exposed to oxidizing agents or sources of heat. Do not store filters where exposure to direct sunlight could occur.

- **Nitroglycerin** [($C_3H_3(NO_3)_3$] for research purposes it is usually in tincture form, mixed with alcohol. Do not allow the carrier to evaporate, as this will result in high explosive nitroglycerin.
- **Oxygen Tanks** can explode due to contact between oil and high pressure oxygen. Do not use oil in connections with an oxygen cylinder or regulator. Do not use soap-based leak detector compounds on the connection that threads of an oxygen cylinder.
- **Ozone** (O_3) is a highly reactive and toxic gas. It forms by the action of ultraviolet light on oxygen (air) and, therefore, certain ultraviolet sources may require venting to the exhaust hood.
- **Palladium or Platinum on Carbon, Platinum Oxide, Raney Nickel, and other Catalysts**, must be carefully filtered from catalytic hydrogenation reaction mixtures. The recovered catalyst is saturated with hydrogen and highly reactive; thus, it will ignite spontaneously on exposure to air. Particularly for large-scale reactions, do not allow the filter cake to dry. Place the funnel containing the still-moist catalyst filter cake into a water bath immediately after completion of the filtration. Another hazard in working with such catalysts is the potential of explosion when adding additional catalyst to a flask in which hydrogen is present.
- **Parr Bombs** used for digestions or hydrogenations have failed and exploded. Handle all high-stress equipment such as bomb calorimeters with care behind bench top shields, and wear proper eye protectors.
- **Perchlorate** use should be avoided whenever possible. Do not use perchlorates as drying agents if there is a possibility of contact with organic compounds, or in proximity to a dehydrating acid strong enough to concentrate the perchloric acid ($HClO_4$) to more than 70% strength (e.g., in a drying train that has a bubble container containing sulfuric acid). Use safer drying agents. Seventy percent (70%) $HClO_4$ can be boiled safely at approximately 200 ^oC, but contact of the boiling undiluted acid or the hot vapor with organic matter, or even easily oxidized inorganic matter (such as compounds or trivalent antinomy), will lead to serious explosions. Do not allow oxidizable substances to contact $HClO_4$. Use beaker tongs, rather than rubber gloves, when handling fuming $HClO_4$. Carry out perchloric acid evaporations and digestions in a dedicated hood that has a good draft, and that is washable. Frequent washing out of the hood and ventilator ducts with water is necessary to avoid the danger of metal perchlorate buildup, which could lead to spontaneous combustion or explosion.
- **Permanganates** are explosives when treated with sulfuric acid. When both compounds are in an absorption train, place an empty trap between them.
- **Peroxides (inorganic)**, when mixed with combustible materials, barium, sodium, and potassium, form explosives that ignite easily.
- **Phosphorus** (P), both red and white, forms of explosive mixtures with oxidizing agents. White (also called yellow) P should be stored under water, in glass, because it is pyrophoric. The reaction of P with aqueous hydroxides gives phosphine (PH_3), a highly toxic gas that can also ignite or explode spontaneously in air.
- **Phosphorus Trichloride** (PCl_3) reacts with water to form phosphorous acid, which decomposes on heating to form phosphine, which may ignite spontaneously in the air or explode. Take care when opening containers of PC13, and do not heat samples that were exposed to moisture without adequate shielding to protect yourself.
- **Picric Acid** [$(NO_2)_3C_6H_2OH$], also known as 2,4,6,-trinitrophenol, can form explosive compounds with many combustible materials. Do not store in metal containers, as this can cause the formation of highly explosive metal picrate salts. Picric acid in saturated aqueous solution is relatively stable, but becomes less stable with age; in solutions of 10% to 40% water, it is considered a flammable solid. If picric acid dries, to less than

10% water), it is a high explosive and must not be touched or disturbed except by the trained high-hazard removal specialists.

- **Piranha Solutions** (mixtures of sulfuric acid and hydrogen peroxide) used for the removal of organic materials which must never be stored, as they are likely to pressurize and explode their container. Make only what you need, and discard immediately after use. Solutions are very energetic and heat to over 100 ^{o}C during mixing; handle with care.
- **Potassium** (K) is in general more reactive than sodium, and ignites quickly on exposure to humid air; therefore, handle it under the surface of a hydrocarbon solvent such as mineral oil or kerosene (see Sodium). Potassium may also form peroxides even while stored under oil.
- **Propargyl Bromide** (C_3H_3Br), is also known as 3-bromopropyne, and unstable water-insoluble compound that is usually stored in a solvent such as toluene. Do not allow propargyl bromide to dry out, do not store it in an area near the heat sources, and do not expose it to mild mechanical shocks.
- **Residues from Vacuum Distillations** (for example, ethyl palmitate) have exploded when the still was vented to the air before the residue was cool. Avoid such explosions by venting the still pot with nitrogen, cooling it before venting, or restoring the pressure slowly.
- **Sodium** (Na) shall be stored in a closed container under kerosene, toluene or mineral oil. Destroy scraps or Na or K by reaction with n-butyl alcohol. Avoid contact with water, as sodium reacts violently with water to form hydrogen with the evolution of sufficient heat to cause ignition. Use sand or Class D extinguishers on alkali metal fires. Do not use CO_2 fire extinguishers.
- **Sodium Amide** ($NaNH_2$) can rapidly absorb water and carbon dioxide from humid air. Oxidation can produce sodium nitrite in a mixture that is unstable and may explode. Store sodium amide in a cool, dry place in a tightly-sealed container under inert gas blanket.
- **Sodium Azide** (NaN_3) can react with copper and lead (including copper and lead in plumbing) to produce explosive copper or lead azide. Use caution when drain disposing substances that contain any amount of sodium azide. Even the trace amounts (‹1%) used as an antimicrobial chemical mixtures and reagents test kits can react with copper or lead in areas such as P-traps; there is the potential for prolonged contact between the azide and lead/copper that might be in these traps. If you drain dispose any substances with trace amounts of sodium azide, flush with copious amounts of water. Sodium azide is also highly toxic, and can decompose explosively due to heat, shock, concussion, or friction. Do not mix with sulfuric or nitric acid.
- **Sulfuric Acid** (H_2SO_4) should be avoided, if possible, as a drying agent in desiccators. If used, place glass beads in it to prevent splashing when the desiccators is moved. Avoid using H_2SO_4 in melting point baths, use silicone oil instead. To dilute H_2SO_4), add the acid slowly to cold water.
- **Tollens Reagents**, which contain an aqueous diamine silver complex $[Ag(NH_3)_2^+]$ and are used to test for aldehydes, must be freshly prepared and NEVER stored for longer than 1-2 hours. Stored Tollens Reagent can form explosive fulminating silver (Ag_3N). Acidify with dilute acid before disposal.
- **Trichloroethylene** (Cl_2CCHCl) reacts under a variety of conditions with potassium or sodium hydroxide to form dichloroacetylene (ClCΞCCl), which ignites spontaneously in the air and detonates readily even at dry-ice temperatures. The compound itself is toxic, so take suitable precautions when using as a degreasing solvent. Methyl chloroform (1,1,1-trichloroethane) is a less toxic substitute.

4.2 Safe Usage of Chemicals

All chemicals can have toxic effects at some dose level and particular route(s) of exposure. It is therefore wise to minimize exposure to chemicals. Chemicals can have local or systematic effects. Local toxicity refers to the direct action of chemicals at the point of contact. Systematic toxicity occurs when the chemical agent is absorbed into the bloodstream and distributed throughout the body, affecting one or more organs. Health effects can be acute or chronic. Acute effects last for a relatively short time and then disappear. Chronic effects are not reversible.

Acute exposures to chemicals are for short periods. Chronic health effects can develop from acute exposures depending on the properties and amounts of the chemical. Acute or chronic adverse health effects can occur with chronic (repeated) exposure to chemicals, even at low concentrations.

4.2.1 Routes of Exposure

Dermal Contact

Skin contact is one of the most common chemical exposure routes in the laboratory settings. Spills and splashes can result in overt skin contamination. In addition, laboratory personnel may unknowingly contaminate themselves when they touch work surfaces, glassware, or equipment contaminated during experiments. A common result of skin contact is localized irritation or dermatitis. However, a number of materials are absorbed through the skin are the hair follicles, sebaceous glands, sweat glands, and cuts or abrasions of the outer layers of the skin. The follicles and the glands contain blood vessels, which facilitate the absorption of chemicals into the body. Chemicals can also enter the body when contaminated hands touch the mouth, nose, eyes, sores or cuts.

Inhalation

Inhalation of toxic vapors, mists, gases, or dust can produce poisoning by absorption through the mucous membrane of the mouth, throat and lungs, and can seriously damage these tissues by local action. Inhaled gases or vapors may pass rapidly through the capillaries of the lungs and enter the circulatory system. The degree of injury through the inhalation of toxic substances depends on the material's toxicity, solubility in tissue fluids, concentrations, and the durations of exposure.

Although inhalation hazards are more often associated with gases and volatile chemicals, both solids and non-volatile liquids can also present an inhalation hazard for laboratory personnel. Laboratory chemicals in the form of dust and particulates can become airborne when transferred from one container to another. Grinding and crushing procedures can also produce aerosols. Splashes created from spills and vigorous shaking and mixing form aerosols. Many of these generated particulates do not settle out but remain suspended in the air and travel along air currents in the room. Some of these particulates can be inhaled and they deposit in the respiratory tract. All laboratory operations involving an open vessel will result in aerosol release. Such operations include weighing, stirring, pouring, pipetting, injections with a needle and syringe, and removing caps and stoppers.

Ingestion

Ingestion of toxic materials in the laboratory can occur when contaminated hands come in contact with mouth or with food stuff. The laboratory environment can contaminate food stuff and utensils. Do not mouth pipette, as this can result in aspiration of toxic materials.

Injection

Accidents involving needles and syringes can result in injection of toxic and/or infectious materials through the skin. Needles and syringes are among the most hazardous items used in the laboratory. Containers of toxic chemicals may break, resulting in hazard from contact with contaminated broken glass.

Ocular Exposure

The eyes are of particular concern, due to their sensitivity to irritants. Ocular exposure can occur via splash, or rubbing eyes with contaminated hands. Few substances are innocuous with eye contact, and several can cause burns and loss of vision. The eyes have many blood vessels, and rapidly absorb many chemicals.

4.2.2 Safe Handling Practices

Access Control

The Laboratory Supervisor or work area supervisor must control access to laboratories or other work places that contain chemicals. Keep the laboratory door closed while experiments are in progress. This practice not only protects persons who might otherwise enter the laboratory, it reduces interruptions to laboratory staff that could lead to accidents. Laboratory fume hoods work best and offer the most worker protection, when the door to the laboratory is closed.

Personal Practices

- Wash your hands immediately after completion of any procedure involving chemicals, and when leaving the laboratory. Soap must be in liquid form, with a pump dispenser.
- Eating, drinking, smoking, chewing gum, applying cosmetics and storing utensils, food and food containers are prohibited.
- Use mechanical pipetting aids for all pipetting procedures. NEVER MOUTH PIPETTE.

Decontamination of Work Surfaces

Protect work surfaces from contamination by using “bench paper” (disposable plastic-backed absorbent paper) or stainless steel trays. Place plastic side down and the absorbent side facing up. Change worn or contaminated bench paper and dispose properly. Decontaminate other items and equipment with appropriate solvents when contaminated during experiments.

Minimizing Aerosols

- Discharge liquids from pipettes as close as possible to the fluid level of the receiving vessel or allowing the contents to run down the wall of the receiving vessel. Dropping the contents from a height generates more aerosols.
- Avoid rapid mixing of liquids with pipettes by alternate suction and expulsion, or forcibly expelling material from a pipette.
- Take extra care when discarding contaminated gloves or plastic-backed absorber paper used to cover the work surface, to avoid aerosolizing contaminants.
- Clean floors with a wet mop or with a vacuum cleaner equipped with a HEPA filter, as dry sweeping or dry mopping contaminated laboratory floors could aerosolize contamination.

Carcinogens

- Appropriate pre-employment and periodic medical examinations should be provided for persons handling or potentially being exposed to chemical carcinogens. The pre-employment examination should include a personal history review of the individual, his family and his occupational background, with emphasis on genetic and environmental factors known to be associated with an increased incidence of cancer.
- Persons having reduced immunological competence, those undergoing treatment with steroids, pregnant women and chronic tobacco users should be cautioned against access to areas where chemical carcinogens are processed.
- The Laboratory In-charge is responsible for the preparation of general safety protocols for each carcinogen to be handled in a test. The protocols should include specific details identifying the physical and toxicological properties of the carcinogen and the use, storage, emergency treatment and disposal procedures.
- When working with carcinogens, wear protective apparel, including eye protectors. A change area and shower must be readily available.
- Thoroughly wash hands, forearms, face and neck after each episode of handling.
- Work should be performed in a regularly maintained hood with an average linear face velocity of 100 - 120 feed per minute, with complete filtering or treatment of the air before release.
- Housekeeping and cleanup should stress aerosol suppression and preclude dry sweeping.
- Carcinogen waste shall be collected, labeled, and disposed of by a licensed chemical disposal company.
- All containers of carcinogen should be clearly labeled and kept in a hood designated only for carcinogen use.
- In the case of any carcinogenic spill or contamination, shower immediately.

Cryogenic Liquids

Cryogenic liquids are pressurized liquids formed by compressing gases to a point where the temperature reaches-60 degrees C to -270 degrees C). They are particularly hazardous because they can explode or cause structural materials to become fatigued and brittle.

The low boiling points of cryogenic liquids (-60 C to -270 C) require that they be kept liquefied under pressure. Many are used at room temperature which means that they are at their boiling point when actually used. Carelessness at this point may result in frostbite and frozen skin tissue through body contact or asphyxiation if inhaled directly from the pressurized cylinder.

Please refer to *QU SOP-03 Compressed Gas Cylinders* for the safety practices to be considered when using or handling cryogenics.

4.2.3 Storage

Inventory and Inspection

- Each laboratory shall maintain an inventory of the chemicals stored in the laboratory.
- Designate a storage place for each chemical, and return it to that storing place after each use.
- Store chemicals by hazard class, not alphabetically, and post storage areas the exact location of the chemical groups.
- Inspect chemical storage areas at least annually for outdated or unneeded items, illegible labels, leaking containers, etc.

Proper Sealing of Chemical Containers

- To prevent leakage, odors, or reaction with air, tightly seal all containers of highly toxic, highly volatile, malodorous, carcinogenic or reactive chemicals.
- Make sure that the caps and other closures are tight on all hazardous chemicals.
- A limited exception is freshly-generated mixtures such as acids and organics that may generate gas pressure sufficient to burst a tightly sealed bottle. Keep the lids loose until sufficient time passes to complete the reactions, and then tightly close the caps.
- Use a screw-cap with a conical polyethylene or Teflon insert.
- Seal the caps with tape or Para film as further precaution.
- Additional protection include wrapping in an absorbent paper & sealing inside plastic bag & and storing the bag inside a metal can with a friction-fitting lid.

Segregation of Chemicals

The storage of hazardous materials should be supervised by a competent, trained person to ensure that the materials are properly segregated. Incompatible materials shall be segregated to prevent accidental contact with one another. Dry materials, liquids, and gases should be stored separately from each other. Further separation of the materials based on hazard class should be made. Once separated into hazard classes, chemicals may be stored alphabetically. Only use approved storage containers and safety cans for flammable liquids. Always use spill trays under containers of strong corrosive reagents. Do not store liquids above eye level. The following are guidelines for hazardous material segregation:

Group A – Acids, Inorganic

- Store large bottles of acids in special cabinets or on low shelves.
- Place acids in plastic trays for secondary containment in case of breakage.
- Segregate inorganic and oxidizing acids from organic compounds including organic acids and other combustible materials.
- Store acids separate from bases and other reducing agents.
- Inorganic salts, except of heavy metals, may be stored in this group.
- Segregate nitric acid (> 40%) from inorganic acids.
- Glacial acetic acid should be stored with flammable and combustible materials since it is combustible.

Group B – Bases

- Segregate bases from acids and oxidizers on shelves near the floor.
- The preferred storage container for inorganic hydroxides is polyethylene instead of glass.
- Place containers in trays for secondary containment

Group C – Organic Chemicals

- Segregate organics compounds from the inorganics.
- Organic and inorganic materials with National Fire Protection Association (NFPA) 704 or Workplace Hazardous Material Information System (WHMIS) reactive rating of two (2) or less may be stored together. Chemicals with a reactive hazard rating of three (3) or four (4) are to be stored separately.

Group D – Flammable and Combustible Organic Liquids

- No more than 230 liters of Class 1 flammable liquids (flash point below 37.8° C) or Class II combustible liquids (*flash point between 37.8° C and 60° C) may be stored in flammable liquid storage cabinets. The 230-liter limit per room is based on two storage cabinets, with a maximum of 115 liters per cabinet*).
- No more than 460 liters of a Class III combustible liquid (*flash point between 60° C and 93° C*) may be stored in a flammable-liquids storage cabinet.
- Store flammable and combustible materials away from oxidizers.

Group E – Inorganic Oxidizers and Salts

- Store inorganic oxidizers away from combustible alkaline metals, formic acid and other reducing agents.
- Inorganic salts may also be stored in this group.
- Store ammonium nitrate separately.

Group F – Organic Peroxides and Explosives

- Organic peroxides and explosives are shock and heat sensitive chemicals, and should be stored in a dedicated cabinet.

Group G – Reactive

- Store water reactive chemicals in a cool dry place away *from water sources.*
- *Alkali metals (lithium. Sodium, potassium, rubidium and cesium*) should be stored under mineral oil or in waterproof enclosures such as glove boxes.
- Store white or yellow phosphorous under water in glass-stopper bottles inside a metal can for added protection.

Group H – Cyanides and Sulfides

- Isolate from acids and other oxidizers.

Flammable Liquids Storage outside a Cabinet

- Storage of flammable liquids outside a storage cabinet shall be avoided when possible. Flammable liquids that are not in use should be stored in an appropriate cabinet.
- The maximum quantity of flammable liquids permitted to be stored in a laboratory outside the flammable-liquids cabinet varies depending on the design of the research building.
- Flammable liquids should not be stored in refrigerators unless it is UL approved for flammable liquid storage. Storage of flammable liquids in household grade refrigerators is a fire hazard. Household grade refrigerators should be labeled: "No food or flammable liquid storage".

4.2.4 Disposal

Ensure that all chemicals are disposed in accordance with *QU SOP-03 Hazardous Waste Disposal*.

4.2.5 Transportation

The transportation of hazardous chemicals in laboratory buildings provides the greatest potential for chemical exposure to the building occupants. Spills occurring outside storerooms and laboratories may lead to hazardous concentrations of vapors and gases being distributed throughout the building.

Freight elevators shall be used where available to transport hazardous materials. Under no circumstances should passenger elevators be used for the transportation of hazardous materials if freight elevators are available.

Flammable liquids shall be transported in rugged pressure-resistant safety cans.

Original containers of flammable liquids shall be placed in an outside container or acid-carrying bucket.

No more than 5 gallons of flammable liquids in glass containers shall be transported on the freight elevator unless the original shipping carton (box) is used and the materials are on an appropriate cart.

4.3 Special Handling for Hydrofluoric Acid

Hazards

Hydrofluoric acid (HF) differs from other acids because it readily penetrates the skin and dissociates into fluoride ions, causing destruction of deep tissue layers, including bone. The fluoride ion affects tissue integrity and metabolism by liquefaction necrosis, decalcification and destruction of bone, and production of insoluble salts. Loss of calcium (hypokalemia) results from precipitation of calcium from the blood as CaF_2. This results in calcium loss from the bones to equilibrate the decreased serum calcium. The development of hypokalemia can be rapidly fatal because calcium is important for muscles, including the cardiac muscle (heart), to function properly. Fluoride ions might also combine with potassium and magnesium ions, leading to myocardial and arrhythmia. Death from metabolic acidosis, hypokalemia, or ventricular arrhythmia can occur several hours after exposure.

Pains associated with skin exposure to HF may not occur for 1-24 ours. Unless HF is rapidly neutralized and combines with the fluoride ions, tissue destruction may continue for days and result in limb loss or death. HF is similar to other acids in that the initial extent of burn depends on the concentration, temperature, and duration of contact with the acid. Eye exposure to concentrations of HF greater than 0.5 % can result in severe ocular damage, with delayed signs and symptoms.

Hydrofluoric acid vapors are also hazardous. Ocular irritation and injury can occur from working with HF outside a vented enclosure (laboratory fume hood). Inhalation can cause severe throat irritation, cough, dyspnea, cyanosis, lung injury and pulmonary edema. In severe exposure cases, these can result in death.

Handling

Familiarize yourself with the hazard specific to HF before handling. Consult the MSDS and label information. Always handle HF in a properly functioning laboratory fume hood and in an area equipped with an eyewash and emergency shower.

Required Personal Protective Equipment:

- Goggles
- Face shield (plastic)
- Gloves: Thin disposable gloves (*such as 4, 6, 8 mil blue nitrile gloves*) used laboratory operations provide a contact barrier only and should be disposed immediately when contamination is suspected. Thicker (10-12 mil) PVC or neoprene gloves provide better resistance to HF but do not provide the necessary dexterity. Thinner PVC or poly gloves can provide some resistance to HF, but shall require immediate changing at the first sign of contamination. Do not wear disposable gloves without double gloving because of the potential for exposure through pinholes.
- Acid resistant apron
- Long pants and sleeves
- Closed toe shoes

Incompatibilities and Storage

- Store HF in a cool, dry place away from incompatible materials.
- HF reacts with many materials; avoid contact with glass, concrete, metals, water, other acids, oxidizers, reducers, alkalis, combustibles, organics and ceramics.
- Store in containers made of polyethylene or fluorocarbon plastic, lead, or platinum.
- Place storage bottles in polyethylene secondary containment trays.
- Never store HF, of HF waste in glass containers.

4.4 Compressed Gases Handling

Refer to *QU SOP-03 Compressed Gas Cylinders* for the safety procedures when dealing with compressed gases.

4.5 Workplace Hazardous Materials Information System (WHMIS)

Workplace Hazardous Materials Information System (WHMIS) is a communication system that provides information to all staff, faculty and students about hazardous materials used within workplaces.

The system has three components that provide information about the materials you work with, about the physical agents you are exposed to and the hazards that exist in the working environment.

Material Safety Data Sheet - Basic information about the specific material including:
how it should be handled and/or stored, protective measures, and emergency procedures.

Labels - A label displayed on each package or container of a controlled product used in the workplace. Standardized warning symbols are part of the WHMIS Classification System.

Worker Education - Training programs must be provided to everyone who works with the hazardous materials.

4.5.1 Hazard Classification System

The WHMIS Hazard Classification System identifies six types, or broad classes of hazardous materials. Divisions are provided in some classes to separate different groups of hazardous materials within a class. The classification system determines whether a product meets the criteria for inclusion in any of the WHMIS classes or is subject to the WHMIS information requirements. Classification affects whether the product is included within WHMIS, but also the:

- Content of labels, particularly hazard symbols, risk statements and precautionary measures.
- Content of material safety data sheets, and
- Instruction provided to workers.

A system of standardized symbols on WHMIS labels, each with a circular border, provides a uniform way to identify hazards.

Class A: Compressed Gas

The symbol for compressed gas is the outline of a compressed gas cylinder. A compressed gas product is in a gaseous state and is kept under pressure.

Class A materials include compressed gases, dissolved gases or gases liquefied by compression or refrigeration.

Some compressed gases are also flammable and combustible. Others are also materials causing immediate and toxic effects. Whenever a controlled product falls into two or more classes, two or more hazard symbols are provided.

Class B: Flammable and Combustible Material

The symbol for Flammable and Combustible is a flame. This classification refers to a solid, liquid or a gas that will ignite and continue to burn if exposed to a flame or ignition.

Flammable materials will burn easily at or about room temperature (Flash point 38 degrees C or below) and Combustible material will burn when heated.
Six types of materials belong to this class:

- Flammable Gases: Examples - propane and hydrogen.
- Flammable Liquids: Example - gasoline.
- Combustible Liquids: Examples - paint thinner and diesel fuel.
- Flammable Aerosols: Examples - hair spray, engine starter fluid and penetrating oil.
- Reactive Flammable Materials: Examples - celluloid and metallic sodium.
- Combustible Solids: Examples - Wood and paper.

Class C: Oxidizing Materials

The symbol for Oxidizing Materials is a flame above an “O”, which stands for “Oxygen”. Oxidizing materials will cause or assist to cause fires in surrounding materials by supplying oxygen. Oxygen is required for all fires, and any substance that increases the supply of oxygen will increase the chance of fire. Examples include: peroxide bleach, nitrites and chlorates.

Class D Poisonous and Infectious Material

Materials that fall into Class D are further divided into three separate divisions:

Class D1: Materials Causing Immediate and Serious Effect

The symbol is the familiar skull and crossbones. Examples include bleach, hydrogen sulphide, chlorine, strychnine and cyanides.

Class D2: Materials Causing Other Toxic Effect

The symbol is a “T” made into an exclamation mark that stands for “TOXIC”. These are materials that may cause harmful effects usually sometime after the first or repeated exposures. Examples include: vapors of solvents, mercury, some herbicides and aromatic solvents.

Class D3: Biohazardous and Infectious Material

This symbol looks like a cell that is dividing. Biohazardous infectious materials are organisms (and the toxins of organisms) that cause diseases such as viruses, bacteria and fungi. Examples include: vaccines and science laboratory classes.

Class E: Corrosive Material

The symbol for Corrosive material is liquid being poured onto a hand and a piece of solid material causing damage to the hand and to the material itself. Corrosive materials may cause burns and destroy tissues. They can also destroy other materials. Examples: sulphuric acid, hydrochloric acid and anhydrous ammonia.

Class F: Dangerously Reactive Materials

The symbol is an exploding test tube inside a capital "R", which stands for "REACTIVE". A substance is considered to be dangerously reactive when it will:

- React with water to produce a poisonous gas.
- Self-react if the container is heated, pressurized, or shaken; or
- Self-react because of age.

4.5.2 Safety Data Sheet

Safety Date Sheet is a report prepared by manufacturers containing useful information to ensure their chemicals are handled and stored properly and identifying the types of precaution, protective equipment, emergency preparedness that must be used for staff and students' safety.

Safety Data Sheet (SDS) is required for all type of chemicals (liquid, solid, gases) in the University. Storage area for chemicals will be provided with Safety Data Sheet (SDS).

The OSHA Hazard Communication Standard (29 CFR 1910.1200) requires manufacturers to provide MSDS at no cost. The following information is to be included:

Section I of the SDS lists information identifying the manufacturer and the product. It includes:

- Manufacturer's name, address and telephone number
- Number to call in case of emergency
- Chemical name and synonyms
- Trade name and synonyms
- Chemical family and formula
- Chemical Abstract Service (CAS) number that is a unique identification number for chemical reagents.
- Date of preparation

Section II describes the various hazardous ingredient(s) contained in the product, the percentages of ingredient(s), and exposure limits when appropriate. This will include all hazardous chemicals that comprise 1% or greater of the mixture will be identified. Carcinogens must be listed if the concentrations are 0.1% or greater.

Section III describes the physical properties of the material. Physical properties include:

- Boiling point
- Specific gravity
- Vapor pressure
- Percent volatile
- Vapor density
- Evaporation rate
- Solubility in water
- Appearance and odor

Section IV describes the fire and explosion hazard data for the material and other fire and explosion data. The appropriate extinguishing agent for fires involving the material will be listed. Special firefighting procedures may also be listed.

Section V describes the known health hazard data for the material and exposure limits. Symptoms or the health effects of an overexposure are listed. This information will help the user and medical personnel recognize if an overexposure has occurred.

- Threshold limit value (TLV)
- Existing medical conditions that may be aggravated by exposure
- Effects of overexposure (e.g., headache, nausea, narcosis, eye irritation, Weakness, skin rashes, etc.)
- Primary routes of exposure (i.e., inhalation, skin, ingestion)
- Cancer or other special health hazards
- Emergency and first aid procedures

Section VI describes reactivity data; that is, the material's ability to react and release energy or heat under special conditions or when it comes in contact with certain substances.

Section VII gives instructions for the steps to be taken in case of an accidental release or spill. The steps normally include information on containment, evacuation procedures, and waste disposal. The statements on the MSDS are general; more specific information is available from the appropriate Work Instruction.

Section VIII describes the protective equipment for the individual who might have to work with such substances. This section normally describes worst case conditions; therefore, the extent to which personal protective equipment is required as task dependent. Always review the appropriate Standard Operating Procedure. Equipment may include:

- Respiratory equipment
- Ventilation
- Protective gloves
- Eye protection
- Other protective equipment (i.e., special clothing).

Section IX describes handling and storage procedures to be taken with the material. Information may include statements such as: keep container closed; store in a cool, dry, well ventilated area; keep refrigerated; avoid exposure to sunlight.

Section X describes any special precautions or miscellaneous information regarding the material. In some cases, manufacturers may choose to withhold certain information on a MSDS provided the information is trade secret. Regardless of the existence of trade secrets, the SDS must still contain all relevant hazard, protection, and health information.

Some SDS may not contain all the ten sections or the information may be in a slightly different order. However, the basic information defined above must be provided.

Some SDSs are more complete than others. Do not assume everything you need to know is contained on the SDS. Do not assume if a section is left blank that there is no risk.

4.5.3 WHMIS Labels

Supplier Labels

Suppliers of WHMIS controlled products to workplaces at Qatar University, whether importing, producing, or selling these products, must affix a supplier label**.** Supplier labels must:

- Have the distinctive cross-hatch border in a color that will contrast with the background on which it appears.
- Be placed on the hazardous material or container so that it is visible under normal storage and use.

Supplier labels must include:

- **Product Identification**
  The common name, chemical name, trade name, generic name, brand name, code name, or code number of a hazardous material.
- **Hazard Symbol**
  A specific WHMIS symbol that represents one or more of the hazard classifications that applies to the product.
- **Risk Phrase**
  A brief description of the hazard and the effects of harmful exposure to the body.
- **Precautionary Measures**
  Brief instructions for the safe use of the material.
- **First Aid Measures**
  A brief description of treatment for exposure to the material.
- **Supplier Identifier**
  The name of the suppler.
- **Reference to the SDS**
  A statement indicating that a copy of the applicable SDS is readily available in the workplace.

Workplace Labels

Workplace label must be placed on containers that are filled from suppliers' containers, and/or when a supplier label becomes illegible or is removed from the product.

Workplace labels are designed, attached and required for:

- Portable containers into which product has been transferred.
- Supplier containers with illegible labels (unless a supplier label is available).
  These labels must include:
  - **Product Identification**
    The common name, chemical name, trade name, generic name, brand name, code name, or code number of a hazardous material.
  - **Safe Handling Instructions**
    This includes unique risks associated with the normal use of the controlled product and the possible emergencies.
  - **Reference to the SDS**
    A statement indicating that a copy of the applicable SDS is readily available in the workplace
    The workplace label may be any size, shape or color and there are no language requirements, but it must be clearly visible and easy to read.
    The cross-hatch border, WHMIS symbols and phrases may appear on the workplace label, but they do not constitute requirements.
    Both labels below are acceptable.

4.5.4 Worker Education

Refer to *QU HSMS Section 11.0 Training and Competency* for training requirements related to chemical safety.

4.6 National Fire Protection Association (NFPA) 704 Diamond

The NFPA 704 Diamond is a standard placard used to identify the level of chemical hazard at fixed locations, such warehouses, storage tanks, and storage sheds. The NFPA diamond also is used on some transported containers. It's sometimes called the "fire diamond."
The NFPA 704 diamond (shown below) is divided into four colored quadrants. Each quadrant provides information about the materials inside:

Within the blue, red, and yellow quadrants is a number from 0 to 4. The number indicates the degree of risk associated with the material. The higher the number, the higher the risk. For some materials, the white quadrant contains symbols indicating special hazards. The meaning of each code number and symbol is shown below.
If more than one chemical is present at a facility, the NFPA diamond indicates overall hazard at that location, *not* the hazard posed by a particular chemical. It shows the highest of each of the four hazards present. For example, it may be that one chemical poses the highest health hazard while another one poses the highest fire hazard.
If there's no NFPA diamond at a facility, don't assume that there are no dangerous chemicals present. Sometimes, a diamond may be missing or displayed in a location where it isn't visible to responder.

Blue represents health hazard. **4** – Deadly **3** – Extreme Danger **2** – Hazardous **1** – Slightly Hazardous **0** – Normal Material	**Red represents fire hazards (**Flash Point**)** **4** Below 73 °F **3** Below 100 °F **2** Above 100 °F ≤ 200 °F **1** Above 200 °F **0** Will not burn
Yellow represents reactivity **4** – May detonate **3** – Shock and heat may detonate **2** – Violent chemical change **1** – Unstable if heated **0** – Stable	**White represents specific hazards** Oxidizer - OX Acid - ACID Alkali - ALK Corrosive - CORR Use NO WATER - W Radioactive - ☢

4.7 Safe Work Practices & Procedures for Labs Equipment

4.7.1 Refrigerators and Freezers

The potential hazards posed by the laboratory refrigerators and freezers involve vapors from the contents, the possible presence of incompatible chemicals and spillage.

- Only refrigerators and freezers specified for laboratory use should be utilized for the storage of chemicals. These refrigerators have been constructed with special design factors, such as heavy-duty cords and corrosion resistant interiors to help reduce the risk of fire or explosions in the lab.
- Standard refrigerators have electrical fans and motors that make them potential ignition sources for flammable vapors. Do not store flammable liquids in a refrigerator unless it is approved for such storage. Flammable liquid-approved refrigerators are designed with spark-producing parts on the outside to avoid accidental ignition. If refrigeration is needed inside a flammable-storage room, you should use an explosion-proof refrigerator.
- Frost-free refrigerators should also be avoided. Many of them have a drain or tube or hole that carries water and possibly any spilled materials to an area near the compression, which may spark. Electric heaters used to defrost the freezing coils can also spark.
- Only chemicals should be stored in chemical storage refrigerators; lab refrigerators should not be used for food storage or preparation. Refrigerators should be labeled for their intended purpose: “No Food or Drink should be Stored in this Refrigerator” or “Refrigerator For Food Only”.
- All materials in refrigerators or freezers should be labeled with the contents, owner, date of acquisition or preparation and nature of any potential hazard. Since refrigerators are often used for storage of large quantities of small vials and test tubes, a reference to a list outside of the refrigerator could be used. Labels and ink used to identify materials in the refrigerators should be water-resistant.
- All containers should be sealed, preferably with a cap. Containers should be placed in secondary containers, or catch pans should be used.
- Loss of electrical power can produce extremely hazardous situations. Flammable or toxic vapors may be released from refrigerators and freezers as chemicals warm up and/or certain reactive materials may decompose energetically upon warming.

4.7.2 Stirring and Mixing Devices

The stirring and mixing devices commonly found in laboratories include stirring motors, magnetic stirrers, shakers, small pumps for fluids and rotary evaporators for solvent removal. These devices are typically used in laboratory operations that are performed in a hood, and it is important that they are operated in a way that precludes the generation of electrical sparks.

- Only spark-free induction motors should be used in power stirring and mixing devices or any other rotating equipment used for laboratory operations. While the motors in most of the currently marketed stirring and mixing devices meet this criterion, their on-off switches and rheostat-type speed controls can produce an electrical spark because they have exposed electrical conductors. The speed of an induction motor operating under a load should not be controlled by a variable autotransformer.
- Because stirring and mixing devices, especially stirring motors and magnetic stirrers, are often operated for fairly long periods without constant attention, the consequences of stirrer failure, electrical overload or blockage of the motion of the stirring impeller should be considered.

4.7.3 Heating Devices

Most labs use at least one type of heating device, such as ovens, hot plates, heating mantles and tapes, oil baths, salt baths, sand baths, air baths, hot-tube furnaces, hot-air guns and microwave ovens. Steam-heated devices are generally preferred whenever temperatures of 100^{o} C or less are required because they do not present shock or spark risks and can be left unattended with assurance that their temperature will never exceed 100^{o} C. Ensure the supply of water for steam generation is sufficient prior to leaving the reaction for any extended period of time.

A number of general precautions should be taken when working with heating devices in the laboratory. When working with heating devices, the following should be considered:

- The actual heating element in any laboratory heating device should be enclosed in such a fashion as to prevent a laboratory worker or any metallic conductor from accidentally touching the wire carrying the electric current.
- Heating device becomes so worn or damaged that its heating element is exposed; the device should be either discarded or repaired before it is used again.
- The external cases of all variable autotransformers have perforations for cooling by ventilation and, therefore, should be located where water and other chemicals cannot be spilled onto them and where they will not be exposed to flammable liquids or vapors.
- Fail-safe devices can prevent fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent or loss of cooling. Some devices will turn off the electric power if the temperature of the heating device exceeds some preset limit or if the flow of cooling water through a condenser is stopped owing to the loss of water pressure or loosening of the water supply hose to a condenser.

4.7.4 Ovens

Electrically heating ovens are commonly used in the laboratory to remove water or other solvents from chemical samples and to dry laboratory glassware. Never use laboratory ovens for human food preparation.

- Laboratory ovens should be constructed such that their heating elements and their temperature controls are physically separated from their interior atmospheres.
- Laboratory ovens rarely have a provision for preventing the discharge of the substances volatilized in them. Connecting the oven vent directly to an exhaust system can reduce the possibility of substances escaping into the lab or an explosive concentration developing within the oven.
- Ovens should not be used to dry any chemical sample that might pose a hazard because of acute or chronic toxicity unless special precautions have been taken to ensure continuous venting of the atmosphere inside the oven.
- To avoid explosion, glassware that has been rinsed with an organic solvent should be rinsed again with distilled water before being dried in an oven.
- Bimetallic strip thermometers are preferred for monitoring oven temperatures. Mercury thermometers should not be mounted through holes in the top of ovens so that the bulb hangs into the oven. Should a mercury thermometer be broken in an oven of any type, the oven should be closed and turned off immediately, and it should remain closed until it is cooled off. All mercury should be removed from the cold oven with the use of appropriate cleaning equipment and procedures in order to avoid mercury exposure.

4.7.5 Hot Plates

Laboratory hot plates are normally used for heating solutions to 100° C or above when inherently safer steam baths cannot be used. Any newly purchased hot plates should be designed in a way that avoids electrical sparks. However, many older hot plates pose an electrical spark hazard arising from either the on-off switch located on the hot plate, the bimetallic thermostat used to regulate the temperature or both. Laboratory workers should be warned of the spark hazard associated with older hot plates.

In addition to the spark hazard, old and corroded bimetallic thermostats in these devices can eventually fuse shut and deliver full, continuous current to a hot plate.

- Do not store volatile flammable materials near a hot plate.
- Limit use of older hot plates to flammable materials.
- Check for corrosion of thermostats. Corroded bimetallic thermostats can be repaired or reconfigured to avoid spark hazards.

Heating mantles are commonly used for heating round-bottomed flasks, reaction kettles and related reaction vessels. These mantles enclose a heating element in a series of layers of fiberglass cloth. As long as the fiberglass coating is not worn or broken, and as long as no water or other chemicals are spilled into the mantle, heating mantles pose no shock hazard.

- Always use a heating mantle with a variable autotransformer to control the input voltage.
- Be careful not to exceed the input voltage recommended by the mantle manufacturer. Higher voltages will cause it to overheat, melt the fiberglass insulation and expose the bare heating element.
- If the heating mantle has an outer metal case that provides physical protection against damage to the fiberglass, it is a good practice to ground the outer metal case to protect against an electric shock if the heating element inside the mantle shorts against the metal case.

4.7.6 Oil, Salt and Sand Baths

Electrically heated oil baths are often used to heat small or irregularly shaped vessels or when a stable heat source that can be maintained at a constant temperature is desired. Molten salt baths, like hot oil baths, offer the advantages of good heat transfer, commonly have a higher operating range (e.g., 200 to 425°C) and may have a high thermal stability (e.g., 540°C).There are several precautions to take when working with these types of heating devices:

- Handle hot oil baths carefully so as not to generate smoke or have the oil burst into flames from overheating.
- Always monitor oil baths by using a thermometer or other thermal measuring devices to ensure that its temperature does not exceed the flash point of the oil being used.
- Fit the oil baths that are left unattended with thermal measuring devices that will turn off the electric power if the bath overheats.
- Mix oil baths well to ensure that there are no “hot spots” around the elements that take the surrounding oil up to unacceptable temperatures.
- Contain heated oil in a vessel that can withstand an accidental strike by a hard object.

- Mount baths carefully on a stable horizontal support such as a laboratory jack that can be raised or lowered without danger of the bath tipping over. Iron rings are not acceptable supports for the hot baths.
- Clamp equipment high enough above a hot bath that if the reaction begins to overheat, the bath can be lowered immediately and replaced with a cooling bath without having to re-adjust the equipment setup.
- Provide secondary containment in the event of a spill of hot oil.
- Wear heat-resistant gloves when handling a hot bath.
- The reaction container used in a molten salt bath must be able to withstand a very rapid heat-up to a temperature above the melting point of salt.
- Keep the salt baths dry since they are hygroscopic, which can cause hazardous popping and splattering if the absorbed water vaporizes during heat-up.

4.7.7 Hot Air Baths and Tube Furnaces

Hot air baths are used in the lab as heating devices. Nitrogen is preferred for reactions involving flammable materials. Electrically heated air baths are frequently used to heat small or irregularly shaped vessels. One drawback of the hot air baths is that they have a low heat capacity. As a result, these baths normally have to be heated to 100^{o}C or more above the target temperature. Tube furnaces are often used for high-temperature reactions under pressure. Consider the following when working with either apparatus:

- Ensure that the heating element is completely enclosed.
- For air baths constructed of glass, wrap the vessel with heat resistant tape to contain the glass if it should break.
- Sand baths are generally preferable to air baths.
- For tube furnaces, carefully select glassware and metal tubes and joints to ensure they are able to withstand the pressure.
- Follow safe practices outlined for both the electrical safety and pressure and vacuum safety systems.

4.7.8 Microwave Ovens

- Microwave ovens used in the laboratory may pose several different types of hazards.
- As with most electrical apparatus, there is the risk of generating sparks that can ignite flammable vapors.
- Metals placed inside the microwave oven may produce an arc that can ignite flammable materials.
- Materials placed inside the oven may overheat and ignite.
- Sealed containers, even if loosely sealed, can build up pressure upon expansion during heating, creating a risk of container rupture.

To minimize the risk of these hazards:

- Never operate microwave ovens with doors open in order to avoid exposure to microwaves.
- Do not place wires and other objects between the sealing surface and the door on the oven’s front face. The sealing surfaces must be kept absolutely clean.
- Never use a microwave oven for both laboratory use and food preparation.
- Electrically ground the microwave. If use of an extension cord is necessary, only a three-pronged cord with a rating equal to or greater than that for the oven should be used.
- Do not use metal containers and metal-containing objects (e.g., stir bars) in the microwave. They can cause arcing.

- Do not heat sealed containers in the microwave oven. Even heating a container with a loosened cap or lid poses a significant risk since microwave ovens can heat material so quickly that the lid can seat upward against the threads and containers can explode.
- Remove screw caps from containers being microwaved. If the sterility of the contents must be preserved, use cotton or foam plugs. Otherwise plug the container with Kim wipes to reduce splash potential.

4.7.9 Ultrasonicators

Human exposure to ultrasound with frequencies between 16 and 100 kilohertz (kHz) can be divided into three distinct categories: airborne conduction, direct contact through a liquid coupling medium, and direct contact with a vibrating solid.

Ultrasound through airborne conduction does not appear to pose a significant health hazard to humans. However, exposure to the associated high volumes of audible sounds can produce a variety of effects, including fatigue, headaches, nausea and tinnitus. When ultrasonic equipment is operated in the laboratory, the apparatus must be enclosed in a 2-cm thick wooden box or in a box lined with acoustically absorbing foam or tiles to substantially reduce acoustic emissions (most of which are inaudible).

Direct contact of the body with liquids or solids subjected to high-intensity ultrasound of the sort used to promote chemical reactions should be avoided. Under mono-chemical conditions, cavitation is created in liquids, and it can induce high-energy chemistry in liquids and tissues. Cell death from membrane disruption can occur even at relatively low acoustic intensities.

Exposure to ultrasonically vibrating solids, such as an acoustic horn, can lead to rapid frictional heating and potentially severe burns.

4.7.10 Centrifuges

- Use only tubes designed for centrifuging.
- Carefully adjust all tubes to equal weight before loading them into the high-speed centrifuge. Have a balanced number of tubes; make up a blank with water if needed, and place them opposite each other in a symmetrical pattern so as to balance the centrifuge.
- Be sure that stoppers in the tube places in a pivot-head centrifuge will clear center (not hit each other) when the tubes swing into horizontal position.
- Keep centrifuge speeds (RPM) within the test specifications, the tube manufacturer’s recommendations, or the centrifuge manufacturer’s recommendations.
- Do not open the centrifuge until it stops completely.
- Turn electrical switch to “OFF” before removing tubes.
- Do not pick up any broken glass with bare hands.
- Explosion- proof centrifuges should be used when using flammable or explosive liquids. The centrifuge should be under negative pressure to a suitable exhaust system.

4.7.11 Rotary Evaporators

Glass components of the rotary evaporator should be made of Pyrex or similar type of glass. Glass vessels should be completely enclosed in a shield to guard against flying glass should the components implode. Increase in rotation speed and application of vacuum to the flask whose solvent is to be evaporated should be gradual.

4.7.12 Glassware

Although glass vessels are frequently used in low-vacuum operations, evacuated glass vessels may collapse violently, either spontaneously from strain or from an accidental blow. Therefore, pressure and vacuum operations in glass vessels should be conducted behind adequate shielding. It is advisable to check for flaws such as star cracks, scratches and etching marks each time a vacuum apparatus is used. Only round-bottomed or thick-walled (e.g., Pyrex) evacuated reaction vessels specifically designed for operations at reduced pressure should be used. Repaired glassware is subject to thermal shock and should be avoided. Thin-walled, Erlenmeyer or round-bottomed flasks larger than 1 L should never be evacuated.

4.7.13 Vacuums

Vacuum pumps are used in the lab to remove air and other vapors from a vessel or a manifold. The most common usages are on rotary evaporators, drying manifolds, centrifugal concentrators (“speed/vacs.”), acrylamide gel dryers, freeze dryers, vacuum ovens, tissue culture filter flasks and aspirators, desiccators, filtration apparatus and filter/degassing apparatus.
The critical factors in vacuum pump selection are:

- Application of the pump will be used on.
- Nature of the sample (air, chemical, moisture).
- Size of the sample(s)

When using a vacuum pump on a rotary evaporator, a dry ice alcohol slurry cold trap or a refrigerated trap is recommended. A Cold Trap should be used in line with the pump when high vapor loads from drying samples will occur. Consult manufacturer for specific situations. These recommendations are based on keeping evaporating flask on rotary evaporator at 400 C. Operating at a higher temperature allows the Dry Vacuum System to strip boiling point solvents with acceptable evaporation rates.
Vacuum pumps can pump vapors from air, water to toxic and corrosive materials like Trifluoroacetic Acid (TFA) and methylene chloride. Oil seal pumps are susceptible to excessive amounts of solvent, corrosive acids and bases and excessive water vapors. Pump oil can be contaminated quite rapidly by solvent vapors and mists. Condensed solvents will thin the oil and diminish its lubricating properties, possibly seizing the pump motor. Corrosives can create sludge by breaking down the oil and cause overheating. Excess water can coagulate the oil and promote corrosion within the pump. Proper trapping (cold trap, acid trap) and routine oil changes greatly extend the life of an oil seal vacuum. Pump oil should be changed when it begins to turn a dark brown color.

Diaphragm pumps are virtually impervious to attack from laboratory chemical vapors. They are susceptible to physical wearing of the membrane if excessive chemical vapors are allowed to condense and crystallize in the pumping chambers. A five minute air purge either as part of the procedure or at day's end will drive off condensed water vapors or further prolong pump life.

Hazardous chemicals can escape from the vacuum pump and the pump should be placed in the hood. Cold traps and acid traps can be helpful, but if allowed to thaw or saturate, they can lose their effectiveness.

4.7.14 Fume Hoods

Laboratory fume hoods are the most important components used to protect laboratory workers from exposure to hazardous chemicals and agents used in the laboratory. Functionally, a standard fume hood is a fire-and chemical-resistant enclosure with one opening (face) in the front, with a movable window (sash) to allow user access into the interior. Large volumes of air are drawn through the face and out the top to contain and remove contaminants from the laboratory.

Fume Hood safe practices are as follows:

- Recommended face velocity is 80 – 120 feet per minute.
- Keep fume hood exhaust fans on at all times.
- If possible, position the fume hood sash so that work is performed by extending the arms under or around the sash, placing the head in front of the sash, and keeping the glass between the worker and the chemical source. The worker views the procedure through the glass, which will act as a primary barrier if a spill, splash, or explosion should occur.
- Avoid opening and closing the fume hood sash rapidly, and avoid swift arm and body movements in front of or inside the hood. These actions may increase turbulence and reduce the effectiveness of fume hood containment.
- Place chemical sources and apparatus at least 6 inches behind the face of the hood. In some laboratories, a colored stripe is painted on, or tape applied to, the hood work surface 6 inches back from the face to serve as a reminder. Quantitative fume hood containment tests reveal that the concentration of contaminant in the breathing zone can be 300 times higher from a source located at the front of the hood face than from a source placed at least 6 inches back. This concentration declines further as the source is moved farther toward the back of the hood.
- Place equipment as far to the back of the hood as practical without blocking the bottom baffle.
- Separate and elevate each instrument by using blocks or racks so that air can flow easily around all apparatus.
- Do not use large pieces of equipment in a hood, because they tend to cause dead spaces in the airflow and reduce the efficiency of the hood.
- If a large piece of equipment emits fumes or heat outside a fume hood, then have a special-purpose hood designed and installed to ventilate that particular device. This method of ventilation is much more efficient than placing the equipment in a fume hood, and it will consume much less air.
- Do not modify fume hoods in any way that adversely affects the hood performance. This includes adding, removing, or changing any of the fume hood components, such as baffles, sashes, airfoils, liners, and exhaust connections.
- Test the airflow alarm prior to use the fume hood to ensure it is operating properly.
- Check the sash height. H & S affixes stickers to vertical-sash laboratory fume hoods to remind users not to work above the recommended sash height. Try to keep the sash closed unless you are setting up or actively using the fume hood. You can raise and lower a correctly operating sash smoothly and with minimal effort. If you have

difficulty operating the sash, or you cannot lower it completely, contact H & S. Do not place equipment, cords, tubing, etc. so that you can lower the sash quickly and completely.

- Do not work with your head breaking the front panel of the fume hood. Sashes at the proper working height generally create a physical barrier between the operator's head and the inside of the fume hood. Working with your head in the fume hood means that the sash is too high.
- Use chemical storage cabinets for long term storage, not your fume hood. Items in a fume hood will impede and disturb the exhaust airflow and potentially reduce or eliminate the safety factor.
- Remove electrical units or other spark sources from the fume hood when flammable liquids or gases are present. Do not place power strips or surge protectors in the fume hood. Plug in all electrical equipment outside of the hood.
- The use of a laboratory fume hood does not sidestep the University guidelines on eye protection. Eye protection is required for all faculty, staff, students, and visitors in the laboratories during experimental procedures that could produce liquid or solid projectiles.
- Face velocity monitoring of fume hoods shall be the responsibility of the H & S.

4.8 Personal Protective Equipment

Provision for new or additional Personal Protective Equipment shall be the responsibility of each Department/ College.

4.8.1 Safety Glasses

- Do not use ordinary prescriptions as they no provide adequate protection from injury to the eyes.
- Use hardened-glass or plastic spectacles with sideway shields.
- Safety glasses use must comply with the Standard for the Occupational and Educational Eye and Face Protection (Z87.1).
- Wearing of contact lenses is allowable provided only if wearing additional eye protection.

4.8.2 Goggles

- Wear goggles when there is a hazard from splashing chemicals or flying particles, e. g. when using glassware under reduced or elevated pressure, or using glass apparatus in combustion or other high temperature operations.

4.8.3 Face Shields

- Wear face shield when there is a need for greater protection from flying particles and harmful liquids to protect face and neck.
- Consider using a face shield when operating a vacuum system (which may implode), or when conducting a reaction with potential for mild explosions.

4.8.4 Gloves

- Wear proper protective gloves for potential contact with corrosive or toxic material, materials of unknown toxicity, sharp edged object, and very hot or cold materials.
- Select gloves based on material handled, the particular hazard involved and their suitability for the operation conducted.
- Consider double gloving (the wearing of two gloves on each hand) when handling highly toxic or carcinogenic materials.
- Before each use, inspect gloves for discoloration, punctures and tears.
- Before removal, wash gloves if the material is impermeable to water.
- Do not reuse single-use disposable gloves.
- Store gloves properly.
- Dispose gloves if already old; shelf life is stamped on the box.
- Dispose gloves on regular trash if they are not contaminated with blood borne pathogens, radionuclides, highly toxic chemicals, or select carcinogens.
- Dispose contaminated gloves in the proper waste stream.
- Do not wear gloves outside the laboratory as this may contaminate surface if touch such as doorknobs, elevator buttons or rest fixtures.
- Wear sturdier gloves such as leather for handling broken glassware, inserting glass tube into rubber stoppers, and similar operations where there is no need protection from chemicals.
- Do not use gloves containing asbestos for high temperature operation, use synthetic material such as Kevlar.
- Do not wear woven gloves while working with cryogens as the liquid may work its way through the glove to the hand. Use glove specifically designed for work with cryogens.

4.8.5 Laboratory Clothing and Protective Apparel

- Wear laboratory coats or protective aprons at all times in the laboratory. Do not wear laboratory coats into food areas or outside of the building where the laboratory is located. If infectious organisms are involved, do not wear outside of the laboratory.
- Do not wear loose (e.g. saris, dangling neckties, oversized or ragged laboratory coats) in the laboratory. Loose or torn clothing and unrestrained long hair can easily catch fire, dip into chemicals, or became ensnared.
- Wear disposable laboratory coat for handling appreciable quantities of known carcinogenic materials.

4.8.6 Respiratory Protection

- Respiratory protection is necessary when working with highly toxic chemicals, biological hazards, or dust known to cause asthma or pulmonary fibrosis. However, respirators are a “last line” of defense, and should not be used until all engineering controls (e.g. ventilation) and work practice controls are exhausted.
- Respirators to be used shall comply with the Respiratory Protection Standard 29 CFR 1910.134.
- Do not use “comfort masks” or surgical masks.

4.9 Emergency Showers and Eyewash Fountains

- Each laboratory area must be equipped with at least one emergency shower and eyewash and shall be located at no more than 10 seconds or 100 feet (walking distance, not a straight line) from any location in the room.
- The shower and fountains must be kept clear of obstruction and clearly labeled by signage on the wall.
- Emergency shower water flow shall be at least 30 gallon-per-minute.
- Eyewash fountains should provide a copious and gentle flow of temperate aerated potable water at 0.4 gallon per minute for a period of 15 minutes (15 minutes of cold water is intolerable.
- Small, hand-held portable eyewash is discouraged since they cannot provide a supply of water sufficient to copiously flush two eyes for at least 15 minutes. Also, the small units provide an environment for the growth of microorganisms. If portable eyewash is use, maintain sterility of the contained water, and use eyewash fountains immediately.
- Some chemicals, even in small amounts, can irritate or damage skin upon contact, flush affected areas with water as soon as possible. Remove personal protective equipment and clothing in the areas of contact once you or your co-workers activated the shower. Fellow workers may need to help remove contaminated clothing. Contact the Medical Clinic (485 1660) immediately. Remain in the shower or continue flushing the eyes for no less than 15 minutes.
- Laboratory in-charge shall be responsible for ensuring that emergency eyewash facilities, both within its laboratory space and in nearby common areas, remain operational and accessible. Check at least a week. A quick (5 second) activation of the eyewash verifies water pressure, and flushes rust, scale, and other debris out of the system.
- H & S shall check the emergency shower and eyewash fountain every week.
- For shower and eyewash that lack floor drains, use buckets, secondary containment trays, or other collection devices to prevent discharge of water directly onto the floor during the test.

4.10 Laboratory Air Quality

- Ensure that the laboratory air is continually replaced, preventing increase of air concentrations of toxic substances during the working day.
- All air from chemical laboratories shall be exhausted outdoors and not re-circulated. Thus, the air pressure in chemical laboratories should be negative with respect to the rest of the building unless the laboratory is also a clean room.
- Laboratory air shall flow from low-hazard to high-hazard use area. Laboratories must be maintained at 47 L/s per module negative relative to non-laboratory spaces. When flow from one area to another is critical to emission and exposure control, airflow monitoring devices shall be installed to signal or alarm a malfunction.
- Relative volumes of supply air and exhaust air to each room should be such that air flows through the opening, including open doorways, at a minimum velocity of 50 fpm and a preferred velocity of 100 fpm in the desired direction.
- Air locks (i.e. vestibules with a door at each end arranged and provided with door-closing mechanisms so that both doors are not open at the same time). They may be used to minimize the volume of supply air required.
- Laboratories in which chemicals and compressed gases are used generally require non-recirculating or 100 % outside air supply systems.

- The release of chemicals into the laboratory shall be controlled by enclosure(s) or captured to prevent any flammable and/or combustible concentrations of vapors from reaching any source of ignition.
- The minimum air-change rate for laboratory space is six air changes per hour regardless of space cooling load.
- Use fume hood device when working with any appreciably volatile substance with a threshold limit value of less than 50 ppm.
- Automatic toxic multi gas monitoring devices shall be installed in new and existing laboratory facilities connected to a local audiovisual alarm within the laboratory area.
- Leave the fume hood "ON" when it is not in active use if toxic substances are stored in it or if it is uncertain whether adequate laboratory ventilation will be maintained when it is off.
- Maintain laboratory temperature between 68^{o}F to 75^{o}F and a humidity of 40% to 60%. Measuring equipment shall be installed to maintain the required temperature and humidity.
- Fume hoods in new laboratory facilities shall have a pressure-independent flow-monitoring device connected to a local audiovisual alarm within the laboratory area. For existing facilities the implementation of airflow devices for fume hoods occurs during the renovation phase.
- Air exhausted from the general laboratory space can be recirculated if the following criteria are met:
  - There are no extremely dangerous or life-threatening materials used in the laboratory.
  - The concentration of air contaminants generated by the maximum credible accident will be lower than short-term exposure limits.
  - The system serving the exhaust hoods is provided with installed spares, emergency power, and other reliability features as necessary.
  - Recirculated air is treated to reduce contaminant concentrations.
  - Recirculated air is monitored continuously for contaminant concentrations or provided with a secondary backup air cleaning device that also serves as a monitor (i.e. HEPA filter in a series with a less efficient filter, for particulate contamination only)
  - Air cleaning and monitoring equipment is maintained and calibrated under a preventive maintenance program.
  - A bypass to divert the recirculated air to atmosphere is provided.

4.11 Unattended Operations

An unattended operation is any unmonitored laboratory activity that has the potential to release water, gas, chemical substances, electrical energy, or chemical energy during foreseeable failures of equipment or utility services.

Frequently, laboratory operations must run continuously or overnight. Equipment and experiments that run unattended to during the day or overnight can cause significant problems and harm to personnel, facilities and equipment. If unattended operations are necessary, it is essential to plan for potential interruptions in utility services such as electricity, water and gas. Perform a hazard analysis to identify potential consequences of failures in utility services or equipment. Design operations to be "fail-safe", so that one malfunction will not cause a propagation of additional failures.

If necessary, arrange for routine inspection of the operation. If appropriate, leave laboratory lights on during unattended operations, and place a sign on the entrance door. The sign will convey critical information to personnel (such as other laboratory personnel, students, and maintenance, housekeepers, or incident / accident responders) who might encounter the unattended operations.

Report or advice of the Campus Facilities Department for the specific areas that need monitoring for the normal power supply to laboratory equipment would enable them to conduct frequent inspections during the unattended operations.

4.12 Laboratory Closeout Procedures

Whenever a Laboratory Supervisor (or a person under their charge performing work with hazardous materials in their laboratory) leaves the university or is transferred to a different location, proper disposition of hazardous materials, glassware, benches, laboratory equipment, fume hoods, etc. are required. Laboratory closeout is also required for renovations or constructions taking place in the laboratory. This undertaking shall be properly coordinated with the Campus Facilities Department prior to the start of laboratory close out.

If proper management of hazardous materials at close-out requires removal services from an outside contractor, the responsible department will be charged for this service.

5 Document Control

This Technical Guideline is a controlled document. The controlled version of this guideline is located on the QU Electronic Documentation Management System.

Any printed copies of this controlled document are reference copies only. It is the responsibility of all of those with printed copies to ensure their copy is kept up to date.

Refer to *QU HSMS Section 16.0 – Document Control and Record Retention*.

6 Appendices

Appendix A: List of Carcinogens

Appendix A: Reproductive Hazards

Appendix C: List of Highly Toxic Chemicals

Appendix A – List of Carcinogens

- **Acetaldehyde**
- **Acetamide**
- **Acetylaminoflu orene, 2-**
- **Acrylamide**
- **Acrylonitrile**
- **Adriamycin (doxorubicin hydrochloride)**
- **Aflatoxins**
- **Aflatoxin M1**
- **Alcoholic beverages (consumption)**
- **Alpha-Chlorinated toluenes**
- **Aluminum production**
- **Amino-2,4-dobromoanthraquinone, 1-**
- **Amino-2-methylanthraquinone, 1-**
- **Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole, 2-**
- **Amino-9H-pyridol[2,3-beta]indole), A-alpha-C(2-**
- **Aminoanthraquinone, 2-**
- **Aminoazobemzene, para-**
- **Aminoazotoluene, ortho-**
- **Aminobiphenyl, 4-**
- **Amitrole**
- **Amsacrine**
- **Analgesic mixture containing phenacetin**
- **Androgenic (anabolic) steroids**
- **Anisidine, ortho-**
- **Antimony trioxide**
- **Aramite**
- **Areca nut**
- **Aristolochia genus herbal remedies**
- **Arsenic and arsenic compounds**
- **Asbestos**
- **Attapulgate (palygorskite), long fibers › 5mm**
- **Auramine, technical-grade**
- **Azacitidine**
- **Azaserine**
- **Azathioprine**
- **Aziridine**
- **Benz(a)anthracene**
- **Benzene**
- **Benzidine**
- **Benzidine-based dyes(technical grade)**
- **Direct Black 38**
- **Direct Blue 6**
- **Direct Brown 95**
- **Benzo(a)pyrene**
- **Benzo(b)fluoranthene**
- **Benzo(j)fluoranthene**
- **Benzo(k)fluoranthene**
- **Benzofuran**
- **Benzotrichloride**
- **Benzyl violet 4B**

- **Beryllium and beryllium compounds**
- **Betel quid with tobacco**
- **Betel quid without tobacco**
- **Bis(2-chloroethyl)-2-napthylamine(Chlornaphazine),N,N-Bis(chloromethyl) ether**
- **Bis(bromomethyl)propane-1,3-diol,2,2-**
- **Bischloroethyl nitrosourea (BCNU)**
- **Bis(chloromethyl) ether**
- **Bitumens, extract of steam-refined and air-refined**
- **Bleomycins**
- **Bracken fern**
- **Bromodichloromethane**
- **Butadiene, 1,3-**
- **Butanediol dimethanesulphonate (myleran), 1,4-**
- **Butanediol dimethanesulfonate (myleran), 1,4-**
- **Butylated hydroxyanisole (BHA)**
- **Butyrolactone, beta-**
- **C.I. Basic Red 9 monohydrochloride**
- **Cadmium and certain cadmium compounds**
- **Caffeic acid**
- **Captafol**
- **Carbon black extract**
- **Carbon tetrachloride**
- **Carrageenan, degraded**
- **Catechol**
- **Ceramic fibers (respirable size)**
- **Chlorambucil**
- **Chloramphenicol**
- **Chlordane**
- **Chlordecone (kepone)**
- **Chlorendic acid**
- **Chloro-4-(dichloromethyl) 5-hydroxy-2(5H)-furanone, 3-**
- **Chloroaniline, para**
- **Chloroethyl-3-cyclohexyl-1-nitrosourea (CCNU), 1-(2-**
- **Chloromethyl-3-4-methylcyclohexyl-1-1nitrosourea, 1-(2-**

- **Chloronated paraffins (C12, 60% Chlorine)**
- **Chlorinated toluenes, alpha- (not necessarily all in froup)**
- **Chlomaphazine**
- **Chloro-2-methylpropene, 1-**
- **Chloro-2-methylpropene, 3-**
- **Chloro-o-phenylenediamine, 4-**
- **Chloro-ortho-toluidine, para-**
- **Chloroform**
- **Chloromethyl ether**
- **Chloromethyl methyl ether (technical grade)**
- **Chlrophenols and their sodium salts**
- **Chlorophenoxy herbicides**
- **Chloroprene**
- **Chlorothalonil**
- **Chlorozotoxin**
- **Chromium compounds, hexavalent**
- **CI Acid red 114**
- **CI Basic Red 9**
- **CI Direct Blue 15**
- **Cisplatin**
- **Citrus Red No. 2**
- **Clonorchis sinensis (Oriental liver fluke)**
- **Coal tar pitches**
- **Coal tars**
- **Cobalt and cobalt compounds**
- **Cobalt metal with tungsten carbide**
- **Cobalt metal without tungsten carbide**
- **Cobalt (II) sulfate and other soluble cobalt (II) salts**
- **Coffee (bladder)**
- **Conjugated estrogens**
- **Creosotes**
- **Cresidue, para-**
- **Cupferron**
- **Cycasin**
- **Cyclophospamide**
- **Cyclosporin A**
- **Dacarbazine**
- **Danthron (1,8-dihydroxyanthraquinone)**
- **Daunomycin**
- **DDT**
- **Diacetylbenzidine, N,N’-**
- **Diaminoanisole, 2,4-**
- **Diaminoanisole sulfate, 2,4-**

- **Diaminodiphenyl ether, 4,4'-**
- **Diaminotoluene, 2,4-**
- **Diazoaminobenzene**
- **Dibenz(a,h)acridine**
- **Dibenz(a,h)anthracene**
- **Dibenz(a,j)acridine**
- **Dibenzo(a,e)pyrene**
- **Dibenzo(a,h)pyrene**
- **Dibenzo(a,i)pyrene**
- **Dibenzo(a,l)pyrene**
- **Dibenzo(c,g)carbazole, 7H-**
- **Dibromo-3-chloropropane, 1,2-**
- **Dibromoethane (EDB), 1,2-**
- **Dibromopropan-1-ol, 2,3-**
- **Dichloroacetic acid**
- **Dichlorobenzene, para-**
- **Dichlorobenzene, 1,4-**
- **Dichlorobenzidine, 3,3'-**
- **Dichloroethane, 1,2-**
- **Dichloromethane (methylene chloride)**
- **Dichloropropene (technical grade), 1,3-**
- **Dichlorvos**
- **Diepoxybutane**
- **Diesel engine exhaust**
- **Diesel fuel (marine)**
- **Di-2-ethylhexyl) phthalate**
- **Diethyl sulphate**
- **Diethylhydrazine, 1,2-**
- **Diethylstilbestrol**
- **Diglycidyl resorcinol ether**
- **Dihydrosafrole**
- **Diisopropyl sulfate**
- **Dimethoxybenzidine, 3,3'-**
- **Dimethoxybenzidine (ortho-dianisidine), 3,3'-**
- **Dimethyl sulphate**
- **Dimethylaminoazobenzene, para-**
- **[(Dimethylamino) methylamino]-5-[2-(5nitro-2-, trans-2-**
- **Dimethylaniline, 2,6- (2,6-xylidene)**
- **Dimethylbenzidine, 3,3'-**
- **Dimethylbenzidine (ortho-toluidine), 3,3'**
- **Dimethylcarbamoyl chloride**
- **Dimethylhydrazine, 1,1-**

- **Dimethylhydrazine, 1,2-**
- **Dimethylvinylchloride**
- **Dinitrofluoroanthrene, 3,7-**
- **Dinitrofluoroanthrene, 3,9-**
- **Dintropyrene, 1,6-**
- **Dinitropyrene, 1,8-**
- **Dinitrotoluene, 2,4-**
- **Dinitrotoluene, 2,6-**
- **Dioctyl Phthalate [Di(2-ethylhexyl)phthalate]**
- **Dioxane, 1,4-**
- **Direct Black 38**
- **Direct Blue 6**
- **Direct Brown 95**
- **Disperse Blue 1**
- **Epichlorohydrin**
- **Epoxybutane, 1,2-**
- **Epstein-Barr virus**
- **Erionite**
- **Estrogens (not conjugated): estradiol-17**
- **Estrogens (not conjugated): estrone**
- **Estrogens (not conjugated): mestranol**
- **Estrogens (not conjugated): ethinylestradiol**
- **Ethylbenzene**
- **Ethyl acrylate**
- **Ethyl methanesulphonate**
- **Ethyl-N-nitrosurea, N-**
- **Ethylene oxide**
- **Ethylene thiourea**
- **Ethylene dibromide**
- **Ethyleneimine**
- **Etoposide**
- **Etoposide in combination with cisplatin and bleomycin**
- **Formaldehyde**
- **Formylhydrazino-4-(5-nitro-2-furyl)thiazole, 2-(2-**
- **Fuel oils (residual, heavy)**
- **Furan**
- **Furyl-3-(5-nitro-2-furyl)acrylamide], AF-2[2-**
- **Fusarium moniliform (toxins derived from)**
- **Gallium arsenide**
- **Gamma radiation (ionizing radiation)**
- **Gasoline**

- **Gasoline engine exhaust**
- **Glasswool (respirable size)**
- **Glu-P-1(2-amino-6-methyldipyridol[1,2-a:3’,2’-d]imidazole)**
- **Glu-P-2(2-aminodipyridol[1,2-a:3’,2’-d]imidazole)**
- **Glycidaldehyde**
- **Glycidol**
- **Griseofulvin**
- **HC Blue No 1**
- **Helicobacter pylori (infection with)**
- **Hepatitis B virus (chronic infection with)**
- **Hepatitis C virus (chronic infection with)**
- **Heptachlor**
- **Hexachlorobenzene**
- **Hexachlorocyclohexanes**
- **Hexachloroethane**
- **Hexamethylphosporamide**
- **Human immunodeficiency virus type 1 (infection with)**
- **Human immunodeficiency virus type 2 (infection with)**
- **Human papilloma virus type 16**
- **Human papilloma virus type 18**
- **Human papilloma virus type 31**
- **Human papilloma virus type 33**
- **Human papilloma virus: some types other than 16, 18, 31 and 33**
- **Human T-cell lymphotropic virus type I**
- **Hydrazine and hydrazine sulfate**
- **Hydrazobenzene**
- **Hydroxyanthroquinone, 1-**
- **Indenol(1,2,3-cd)pyrene**
- **Indium phosphide**
- **IQ (2-amino-3-methyllimidazo[4,5-f]quinoline**
- **Iron-dextran complex**
- **Isoprene**
- **Kaposi’s sarcoma herpesvirus/ human herpesvirus 8**
- **Kepone (chlordecone)**

- **Lasiocarpine**
- **Lead**
- **Lead acetate and lead phosphate**
- **Lead compounds, inorganic**
- **Lindane and other hexachlorocyclohexane isomers**
- **Magenta (containing CI Basic Red9)**
- **Man-made mineral fibers (glasswool, rockwool, slagwool, and ceramic fibers), respirable size**
- **MeA-alpha-C(2-amino-3-methyl-9H-pyridol[2,3-b]indole)**
- **MeIQx(2-amino-3,8-dimethylimidazol[4,5-f]-quinolone**
- **MeIQx(2-amino-3,8-dimethylamidazol[4,5-f] quinozaline**
- **Medroxyprogesterone acetate**
- **Melphalan**
- **Merphalam**
- **Methoxsalen with ultraviolet A therapy (PUVA)**
- **Methoxypsoralen, 8-plus ultraviolet radiation**
- **Methoxypsoralen, 5-**
- **Methyl mercury compounds (methylmercuric chloride)**
- **Methyl methanesulphonate**
- **Methyl chloromethyl ether**
- **Methyl-1-nitroanthraquinone (uncertain purity), 2-**
- **Methyl-N’-nitro-N-nitrosguanidine, N-(MNNG)**
- **Methyl-N-nitrosurethane, N-**
- **Methyl-N-nitrosurea, N-**
- **Methylaziridine (propyleneimine), 2-**
- **Methylazoxymethanol and its acetate**
- **Methyl chrysene, 5-**
- **Methylene bis(2-methylaniline), 4,4’-**
- **Methylenebis (N,N-dimethyl)bensenamine, 4,4’**

- **Methylenebis(2-chloroaniline) (MBOCA), 4,4’**
- **Methylene hloride (dichloromethane)**
- **Methylenedianiline, 4,4’- and its dihydrochloride**
- **Methyleugenol**
- **Methylthiouracil**
- **Metronidazole**
- **Michler’s Ketone**
- **Mineral oils-untreated and mildly treated oils**
- **Mirex**
- **Mitoxantrone**
- **Mitomycin C**
- **Monocrotaline**
- **MOPP an dother combied chemotheraphy for cancer**
- **Morpholinnomethyl-3-[5-nirtofurfurylidene)amino]-2-oxazolidinone,5-**
- **Mustard gas (sulphur mustard)**
- **Nafenopin**
- **Naphthalene**
- **Naphthalamine, alpha-**
- **Naphthylamine, beta-**
- **Neutrons (ionizing radiation)**
- **Nickel and certain nickel compounds**
- **Niridazole**
- **Nitrilotriacetic acid and its salts**
- **Nitro-2-furyl)-2-thiazolyl]acetamide, N-[4-5-**
- **Nitroacenaphthene, 5-**
- **Nitroanisole, 2-**
- **Nitrobenzene**
- **Nitrobiphenyl, 4-**
- **Nitrochrysene, 6-**
- **Nitrofen**
- **Nitrofluorene, 2-**
- **Nitrofurfurylidene)amino]-2-imidazolidinone, 1-[(5-**
- **Nitro-2-furyl)-2-thiazolyl] acetamide, N-[4-(5-**
- **Nitrogen mustard N-oxide**
- **Nitrogen mustard hydrochloride**
- **Nitrogen mustard**
- **Nitrolotriacetic acid and its salts**
- **Nitromethane**
- **Nitropropane, 2-**
- **Nitropyrene, 1-**
- **Nitropyrene, 4-**

- **Nitroso-N-ethylurea, N-**
- **Nitroso-N-methylurea, N-**
- **Nitrosodi-n-butylamine, N-**
- **Nitrosodi-n-propylamine, N-**
- **Nitrosodidiethanolamine, N-**
- **Nitrosodiethylamine, N-**
- **Nitrosodimethylamine, N-**
- **Nitrosomethylamino)propionitrile, 3-(N-**
- **Nitrosomethylamino)1-(3-pyridyl)-1-butanone (NNK),4-(N-**
- **Nitrosomethylethylamine, N-**
- **Nitrosomethylvinylamine, N-**
- **Nitrosomorpholine, N-**
- **Nitrosonomicotine, N- (NNN)**
- **Nitrospiperidine, N-**
- **Nitrosopyrrolidine, N-**
- **Nitrososarcosine, N-**
- **Norethisterone**
- **Ocratoxin A**
- **Oil Orange SS**
- **Opisthoschis viverrini (infection with)**
- **Oxazepam**
- **Oxydianiline, 4,4'-**
- **Oxymetholone**
- **Panfuran S (containing dihydroxymethylfuratrizine)**
- **Phenacetin**
- **Phenazopyridine hydrochloride**
- **Phenobarbital**
- **Phenolphthalein**
- **Phenoxybenzamine hydrochloride**
- **Phenyl glycidyl ether**
- **Phenytoin**
- **PhIP (2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine)**
- **Phosphorus-32 (32P), as phosphate**
- **Plutonium-239(239P) and its decay products, as aerosols**
- **Polybrominated biphenyls (PBBs)**
- **Polychlorinated Biphenyls (PCbs)**

- **Polycyclic aromatic hydrocarbons (PAHs)**
- **Ponceau MX**
- **Ponceau 3R**
- **Potassium bromated**
- **Procarbazine hydrochloride**
- **Progesterone**
- **Progestines**
- **Propane sultone-propiolactone, 1,3-**
- **Propane sultone, 1,3-**
- **Propiolactone, beta-**
- **Propylene oxide**
- **Propylthiouracil**
- **Radionuclides, ∞ and β particle emitting, internally deposited**
- **Radium-224 (224Ra) and its decay products**
- **Radium-226 (226Ra) and its decays products**
- **Radium-228 (228Ra) and its decay products**
- **Radon-222 (222Rn) and its decay products**
- **Refractory ceramic products**
- **Reserpine**
- **Riddelliine**
- **Safrole**
- **Schistosoma haematobium (infection with)**
- **Schistosoma japonicium (infection with)**
- **Selenium sulfide**
- **Shale oils**
- **Silica (crystalline)**
- **Sodium ortho-phenylphenate**
- **Sterigmatocystin**
- **Streptozotocin**
- **Styrene**
- **Styrene oxide (styrene-7,8-oxide)**
- **Sulfallate**
- **Sulphuric acid (occupational exposures to strong inorganic acid mists)**
- **Talc containing asbestiform fibers**
- **Tamoxifen**
- **Tenopiside**
- **Tetrachlorodibenzo-p-dioxin (TCDD), 2,3,7,8-**
- **Tetrachloroethylene (perchloroethylene)**
- **Tetrafluoroethylene**
- **Tetranitromethane**

- **Thioacetamide**
- **Thiodianiline, 4,4’-**
- **Thiotepa[tris(1-aziridinyl)phosphine sulfide]**
- **Thiouracil**
- **Thiourea**
- **Thorium dioxide**
- **Thorium-232 (232Th) and its decay products**
- **Toluene diisocyanates**
- **Toluidine, ortho- (3,3-Dimethylbenzidine)**
- **Toluidine hydrochloride, ortho-**
- **Toxaphene (polychlorinated camphenes)**
- **Trans-2[(Dimethylamino) methylimino]-5[2-(5-nitro-2-furyl)vinyl]-Treosulphan**
- **Treosulphan**
- **Trichloroethylene**
- **Trichlormethine (trimustine hydrochloride)**
- **Trichlorophenol, 2,4,6-**
- **Trichloropropane, 1,2,3-**
- **Tris(2,3-dibromopropyl)phosphate**
- **Trp-P-1(3-Amino-1,4-dimethyl-5H-pyrido[4,3-b]indole)**
- **Trp-P-2(Amino-1-methyl-5H-pyrido[4,4-b]indole)**
- **Trypan blue**
- **Uracil mustard**
- **Urethane**
- **Vanadium pentoxide**
- **Vinyl acetate**
- **Vinyl bromide**
- **Vinyl chloride**
- **Vinyl fluoride**
- **Vinylcyclohexene diepoxide, 4-**
- **Zalcitabine**
- **Zidovudine (AZT, retrovir)**

Appendix B – Reproductive Hazards

This list is provided as a guide and is not all inclusive. Review material safety data sheet.

Name	CAS#	Name	CAS#
Acetaldehyde	75-07-0	Hydrazine(s)	302-01-2
Arsenic	7440-38-2	Hexafluoroacetone	684-16-2
Aniline	62-53-3	Halothane	151-67-7
Aflatoxins	1402-68-2	Karathane	131-72-6
Benzene	71-43-2	Lead (inorganic compounds)	7439-92-1
Benzo(a)pyrene	50-32-8	2-Methoxyethanol	109-86-4
Carbon disulfide	75-15-0	2-Methoxyethyl acetate	110-49-6
Chloroform	67-66-3	Methyl chloride	74-87-3
Chloroprene	126-99-8	N-Methyl-2-pyrrolidone	872-50-4
Dimethyl formamide	68-12-2	Propylene glycol monomethyl ether	107-98-2
Di-sec-octyl-phthalate	117-81-7	Propylene glycol monomethyl ether acetate	108-65-6
Dinitrooctyl phenol	63149-81-5	Propylene oxide	75-56-9
Dithane	111-54-6	Trichloroethylene	79-01-6
2-Ethoxy ethanol	110-80-5	RH-7592	
2-Ethoxyethyl acetate	111-15-9v	Systhane/RH-3866	88671-89-0
Ethylene thiourea	96-45-7	TOK (herbicide)	1836-75-5
2-Ethyhexanol	104-76-7	Toluene	108-88-3
Glycol ethers		Vinyl chloride	75-01-4

Appendix C – List of Highly Toxic Chemicals

Chemical Name	Alternate Name	CAS Number
Abrin	Toxalbumin; Rosary Pea	1393-62-0
Acrolein	2-Propen-1-one	107-02-8
Acrylonitrile	2-Propenenitrile; Cyanoethylene	107-12-1
Actinomycin	Actinomycin C; Oncostatin	1402-38-6
Actinomycin D	Oncostatin K	50-76-0
Activated Factor X	Factor C Activating Enzyme from Russells's Viper Venom	9002-05-5
Aflatoxin B1		1402-68-2
Aldicarb	Propanal, 2-methyl-2-(methylthio)-, O-((methylamino)oxime	116-06-2
Aldrin		309-00-2
Allyl iodide	Iodopropene, 3-	556-56-9
Amanitine, alpha-	Amatoxin, alpha-	23109-05-9
Aminopterin	Aminofolic Acid, 4-	54-62-6
Aminopyridine, 3-	Aminopyridine, m-	462-08-8
Aminopyridine, 4-	Aminopyridine, p-	504-24-5
Amiton		78-53-5
Amiton Oxalate	Tetram Monooxalate	3734-97-2
Amphetamine Sulfate, d-	Benzedrine Sulfate, d-	51-63-8
Amphetamine, d-	Amphetamine,(+)-	51-64-9
Antimony Hydride	Stibine	7803-52-3
Antimycin A	Virosin	1397-94-0
Arsenic Acid	Orthoarsenic Acid	7778-39-4
Arsenic (III) Chloride	Arsenic Trichloride	7784-34-1
Arsenic (III) Fluoride	Arsenic Trifluoride	7784-35-2
Arsenic (III) Oxide	Arsenic Trioxide; Arsenious Oxide	1327-53-3
Arsenic (III) Sulfide	Arsenic Trisulfide	1303-33-9
Arsenic (V) Oxide	Arsenic Pentoxide	1303-28-2
Arsenic (V) Sulfide	Arsenic Pentasulfide	1303-34-0

Chemical Name	Alternate Name	CAS Number
Arsine	Hydrogen Arsenide	7784-42-1
Azinphos-Methyl	Guthion	86-50-0
Beryllium (powdered)		7440-41-7
Beryllium Sulfate Tetrahydrate	Sulfuric acid, beryllium salt (1:1), tetrahydrate	7787-56-6
Bidrin	Dipadrin; Dicrotphos	141-66-2
Bis(2-chloroethyl)-N-nitrosourea, N,N’-	BCNU; Carmustin	154-93-8
Bis(chloromethyl) Ether	BCME	542-88-1
Bis(dimethylamido) fluorophosphates	Dimefox	115-26-4
Boron Trobromide	Boron Bromide	10294-33-4
Boron Trichloride	Boron Chloride	10294-34-5
Boron Trifluoride	Boron Fluoride	7637-07-2
BotulinumToxin B	Botulinum Toxin E	93384-44-2
Bromadiolone	Bromatrol	28772-56-7
Butyronitrile	Cyanopropane, 1-	109-74-0
Calcium Arsenate	Arsenic Acid, Calcium Salt (2:3)	7778-44-1
Calcium Cyanide	Calcid; Cyanogas	592-01-8
Capsaicin	6-Nonenamide, 8-methyl-N-vanillyl-, (E)	404-86-4
Carbachol Chloride	Doryl	51-83-2
Carbofuran	Yaltox	1563-66-2
Carbonyl Cyanide m-Chlorophenylhydrazone	Carbonyl Cyanide 3-Chlorophenyl Hydrazone	555-60-2
Carbophenothion	Acarithion	786-19-6
Chlorfenvinphos	Apachlor	470-90-6
Chlormephos	S-Chloromethyl-o,o-diethylphosphorodithioate	24934-91-6
Chlorophacinone		3691-35-8
Chlorthiophos		21923-23-9
Cholecalciferol	Quintox	67-97-0
Cholera Toxin		9012-63-9
Cisplatin		15663-27-1

Chemical Name	Alternate Name	CAS Number
Colchicine		64-86-8
Copper Acetoarsenite	C.I. Green 21	12002-03-8
Coumaphos		56-72-4
Crimidine	Crimitox	535-89-7
Cyanide		57-12-5
Cyanogen Chloride	Chlorine Cyanide	506-77-4
Cyanuric Fluoride	Trifluorotriazine	675-14-9
Cycloheximide	Actidione	66-81-9
Cytochalasin D	Zygosporin A	22144-77-0
Demecolcine	Colcemid	477-30-5
Dialifor		10311-84-9
Diborane	Boroethane	19287-45-7
Dibutyltin Diacetate		1067-33-0
Dichloroacetylene		7572-29-4
Dichloro-N-methyldiethylamine Hydrochloride, 2,2'-	Nitrogen Mustard Hydrochloride	55-86-7
Dichlorophenylarsine	Phenyl Dichloroarsine	696-28-6
Dichlorvos	DDVP	62-73-7
Dieldrin		60-57-1
Diethyl 4-Nitrophenol Phosphate	Ethyl Paraoxon	311-45-5
Diethyl Chlorophosphate		814-49-3
Digitoxin		71-63-6
Digoxigenim		1672-46-4
Digoxin		20830-75-5
Diisopropyl Fluorophosphate	Isopropyl Phosphorofluoridate	55-91-4
Dimethyl Sulfate	Methyl Sulfate	77-78-1
Dimethylmercury	Methyl Mercury	593-74-8
Dimetilan		644-64-4
Dinitrobutylphenol	DNBP; 2-sec-buty-4,6-Dinitrophenol	88-85-7

Chemical Name	Alternate Name	CAS Number
Dinitro-o-Cresol, 4,6-		534-52-1
Dinitrophenol, 2,4-	Aldifen; DNP,24-	51-28-5
Dioxathion		78-34-2
Disulfoton		298-04-4
Di-tert-butyl Dicarbonate	BOC-Anhydride	24424-99-5
Dithiobiuret, 2,4-	DTB	541-53-7
Doxorubicin (Free Base)	Adriamycin (Free Base)	23214-92-8
Emetine Dihydrochloride		316-42-7
Endosulfan Sulfate		1031-07-8
Endothion		2778-04-3
Endrin	Hexadrin	72-20-8
Ergocalciferol	Vitamin D2	50-14-6
Ergosterol	Provitamin D2	57-87-4
ERL 4221	Chissonox 221 monomer	2386-87-0
Ethion		563-12-2
Ethoprosphos	Ethoprop	13194-48-4
Ethylene Fluorohydrin	Fluoroethanol, 2-	371-62-0
Ethyleneimine	Aziridine	151-56-4
Ethylmercuric Phosphate		2235-25-8
Ethyl-p-nitrophenylbenzenethiophosphate	EPN	2104-64-5
Etorphine	Immobilon	14521-96-1
Fenamiphos		22224-92-6
Fensulfothion	Dasanit	115-90-2
Fluenetil		4301-50-2
Fluoride ion		16984-48-8
Fluorine		7782-41-4
Fluoroacetamide		640-19-7
Fluoroacetic Acid		144-49-0

Chemical Name	Alternate Name	CAS Number
Fonofos		944-22-9
Formaldehyde (gas)	Methyl Aldehyde	50-00-0
Formaldehyde Cyanohydrin	Glycolonitrile	107-16-4
Formetanate Hydrochloride		23422-53-9
Formparanate		17702-57-7
Gitoxin		4562-36-1
Heptachlor		76-44-8
Heptachlor Epoxide		1024-57-3
Hexaethyl Tetraphosphate		757-58-4
Hydrazine		302-01-2
Hydrogen Cyanide	Hydrocyanic Acid	74-90-8
Hydrogen Selenide	Selenium Hydride	7783-07-5
Hygromycin B	Antihelmucin	31282-04-9
Iron Pentacarbonyl		13463-40-6
Isobenzan	Telodrin	297-78-9
Isobutyronitrile	Isopropyl Cyanide	78-82-0
Isocyanatoethyl Methacrylate, 2-		30674-80-7
Isodrin		465-73-6
Lactonitrile		78-97-7
Lannate	Methomyl	16752-77-5
Lepthophos		21609-90-5
Lewesite		541-25-3
Malonitrile	Malononitrile	109-77-3
Mephosfolan		950-10-7
Mercaptofos	Demeton	8065-48-3
Mercury (II) Acetate	Mercuric Acetate	1600-27-7
Mercury (II) Bromide	Mercuric Bromide	7789-47-1
Mercury (II) Chloride	Mercuric Chloride	7487-94-7
Mercury (II) Cyanide	Mercuric Cyanide	592-04-1

Chemical Name	Alternate Name	CAS Number
Mercury (II) Iodide	Mercuric Iodide	7774-29-0
Mercury (II) Nitrate	Mercuric Nitrate	10045-94-0
Mercury (II) Oxide	Mercuric Oxide	21908-52-2
Mercury (II) Thiocyanate	Mercuric Sulfocyanate	592-85-8
Methacrolein Diacetate		10476-95-6
Methamidophos		10265-92-6
Methanesulfonyl Fluoride	Mesyl Fluoride; Fumette	558-25-8
Methidathion	Supracide	950-37-8
Methiocarb	Mecaptodimethur	2032-65-7
Methoxyethylmercuric Acetate		151-38-2
Methoxyethylmercuric Chloride		123-88-6
Methoxyflurane	Metofane; Penthrane	76-38-0
Methyl Chloroformate	Methyl Chlorocarbonate	79-22-1
Methyl Fluoroacetate	Fluoroacetic Aci, Methyl Ester	453-18-9
Methyl Isocyanate		624-83-9
Methyl Lactonitrile, 2-	Acetone Cyanohydrin	75-86-5
Methyl Phosphonic Dichloride		676-97-1
Methylaziridine, 2-	Propyleneimine	75-55-8
Methylhydrazine		60-34-4
Mevinphos	Phosdrin	7786-34-7
Mexacarbate		315-18-4
Mitomycin C	Ametycin	50-07-7
Monensin Sodium	Coban	22373-78-0
Monochrotophos		6923-22-4
Muscimol	Pantherin;Aminomethyl-3-isoxyzole, 5-	2763-96-4
Mustard Gas	Bis(2-Chloroethyl)sulfide	505-60-2
Naphthylthiourea, alpha	ANTU	86-88-4
Nickel Carbonyl	Nickel Tetracarbonyl	13463-39-3
Nickel Cyanide	Dicyanonickel	557-19-7

Chemical Name	Alternate Name	CAS Number
Nicotine		54-11-5
Nicotine Sulfate		65-30-5
Nitric Acid (Red Fuming)		7697-37-2
Nitric Oxide	Nitrogen Monoxide	10102-43-9
Nitrobenzonitrile, p-		619-72-7
Nitrogen Dioxide		10102-44-0
Nitrogen Mustard	Dichloro-N-methyldiethylamine, 2, 2'-	51-75-2
Nitrogen Tetroxide		10544-72-6
Nitrosodimethylamine, N-	Dimethylnitrosamine	62-75-9
Nitrosomethylvinylamine, N-		4549-40-0
Norbormide		991-42-4
Ochratoxin A		303-47-9
Octamethyldiphosphoramide	Octamethylpyrophosphoramide	152-16-9
Osmium Tetroxide		20816-12-0
Ouabain	Acocantherin	630-60-4
Oxamyl		23135-22-0
Oxidiphenoxarsine, 10, 10'-	Vinadine	58-36-6
Oxotremorine		70-22-4
Oxygen Difluoride	Fluorine Oxide; Oxygen Fluoride	7783-41-7
Parathion	Phosphostigmine	56-38-2
Parathion-Methyl	Methyl Parathione; Metaphor	298-00-0
Pentaborane(9)	Nonahydropentaborane	19624-22-7
Pentachlorophenol		87-86-5
Phalloidin	Phalloidon from Amanita Phalloides	17466-45-4
Phenyl Mercaptan	Thiophenol; Benzenethiol	108-98-5
Phenylmercuric Acetate	Phenylmercury Acetate	62-38-4
Phenylmercuric Triethanolamine Lactate		23319-66-6
Phenylphosphine		638-21-1

Chemical Name	Alternate Name	CAS Number
Phenylsilatrane		2097-19-0
Phenylthiocarbamide	Phenyl-2-Thiourea, 1-	103085-5
Phorate		298-02-2
Phosacetim		4104-14-7
Phosfolan		947-02-4
Phosgene	Carbonyl Chloride	75-44-5
Phosphamidon		13171-21-6
Phospine	Hydrogen Phosphide	7803-51-2
Phosphonothioic Acid, Methyl-, o-(4-nitrophenyl)o-phenyl Ester	Colep	2665-30-7
Phosphorous Oxychloride	Phosphoryl Chloride	10025-87-3
Phosphorus Trichloride	Phosphorous Chloride	7719-12-2
Phosphorus, Yellow	Phosphorus White	7723-14-0
Physostigmine	Eserine	57-47-6
Physostigmine Salicylate	Eserine Salicylate	57-64-7
Physostigmine Sulfate	Eserine Sulfate	64-47-1
Picrotoxin	Cocculin	124-87-8
Potassium Arsenite	Arsenenous Acid, Potassium Salt	10124-50-2
Potassium Azide		20762-60-1
Potassium Cyanide		151-50-8
Potassium Silver Cyanide	Silver Potassium Cyanide	506-61-6
Promecarb		2631-37-0
Propanenitrile	Propionitrile; Ethyl Cyanide	107-12-0
Propargyl Alcohol		107-19-7
Propiolactone, beta-	Propiolactone, 1,3-	57-57-8
Puromycin	Achromycin	53-79-2
Ricin		9009-86-3
Sarin	Isopropyl methane flurophosphonate	107-44-8
Selenium Dioxide	Selenium (IV) Dioxide	7446-08-4

Chemical Name	Alternate Name	CAS Number
Sodium Arsenate	Arsenic Acid, Sodium Salt	7631-89-2
Sodium Azide		26628-22-8
Sodium Cyanide		143-33-9
Sodium Dichromate		10588-01-9
Sodium Fluoroacetate	Fluoroacetic Acid, Sodium Salt	62-74-8
Sodium Meta Arsenite		7784-46-5
Sodium Selenate	Selenic Acid, Disodium Salt	13410-01-0
Sodium Selenite	Selenious Acid, Disodium Salt	10102-18-8
Streptonigrin	Bruneomycin	3930-19-6
Strychnine		57-24-9
Strychnine Sulfate	Vampirol	60-41-3
Sulfur Pentafluoride	Sulfur Decafluoride	5714-22-7
Sulfur Tetrafluoride		7783-60-0
Tabun		77-81-6
Tellurium Hexafluoride		7783-80-4
Tetrachlorodibenzo-p-Dioxin, 2,3,7,8-	TCDD, 2,3,7,8-; Dioxine	1746-01-6
Tetraehyl Dithiopyrophosphate	Sulfotep;TEDP	3689-24-5
Tetraethyl Lead	Tetraethyl Plumbane	78-00-2
Tetraethyl Pyrophosphate	Vapatone	107-49-3
Tetraethyltin	Tetraethyl Stannate	597-64-8
Tetrodotoxin	Tetrodotoxin Citrate	4368-28-9
Thallium Malonate	Thallous Malonate	2757-18-8
Thallium Sulfate		10031-59-1
Thallium (I) Acetate	Thallous Acetate	563-68-8
Thallium (I) Carbonate	Thallous Carbonate	6533-73-9
Thallium (I) Chloride	Thallous Chloride	7791-12-0
Thallium (I) Nitrate	Thallous Nitrate	10102-45-1
Thallium (I) Sulfate	Thallous Sulfate	7446-18-6

Chemical Name	Alternate Name	CAS Number
Thallium (III) Oxide	Thallic Oxide	1314-32-5
Thiocarbazide	Thiocarbohydrazide –TCH	2231-57-4
Thiodan	Endosulfan	115-29-7
Thiofanox	Dacamox	39196-18-4
Thionazin		39196-18-4
Thiosemicarbazide	Thiocarbamylhydrazine	79-19-6
Tirpate	2,4-Dimethyl-1,3-dithiolane-2-carboxaldehyde, O-(methylcarbamoyl)oxime	26419-73-8
Toluene Diisocyanate	Methyl-m-phenylene Diisocyanate	26471-62-5
Toluene-2,4-Diisocyanate		584-84-9
Toxaphene	Camphechlor	8001-35-2
Triamiphos		1031-46-6
Tricarbonylmethylcyclopentadienyl Manganese		12108-13-3
Trichloronate	Agrisil; Phytosol	327-98-0
Trimethylpropane Phosphite		824-11-3
Trimethyltin Chloride	Chlorotrimethylstannate	1066-45-1
Triphenyltin Hydroxide		76-87-9
Tris(1-aziridinyl)phosphine Sulfide	Thiotepa	52-24-4
Tris(2-chloroethyl)amine		555-77-1
Tubocurarine	Tubocurarine Hydrochloride	57-94-3
Tungsten Hexafluoride	Tungsten(IV) Fluoride	7783-82-6
Uracil Mustard	5-(Bis-(2-chloroethyl)-amino)-uracil	66-75-1
Valinomycin, (+)-	Valinomicin	2001-95-8
Vanadium(V) Oxide	Vanadium Pentoxide	1314-62-1
Warfarin		81-81-2
Warfarin Sodium	Sodium Coumadin	129-06-6
Yohimbine Hydrochloride		65-19-0
Zinc Phosphite		1314-84-7
Zinc Silicofluoride		16871-71-9