

Chemical Laboratory Safety

While the Chancellor, Vice Chancellors, Deans and Department Heads are responsible for the broad implementation and enforcement of Technion's Safety and health policy, the daily responsibility for the adherence to safe laboratory practices in chemical and biological laboratories rests with the PI/Laboratory Supervisor.

All personnel (PIs, laboratory managers/engineers, employees and students) have a duty to fulfill their obligations with respect to maintaining a safe work environment.

Do not work in a chemical laboratory without obtaining appropriate training and meticulously read the safety sheets of the materials involved in the experiment. Basic safety training for chemical, biological and medical laboratory workers can be found on the safety website:
<http://safety.net.technion.ac.il>.

Before commencing work in the laboratory, familiarize yourself with all the main relevant safety procedures and equipment and their location.

Below are the main items:

Num.	Safety equipment	Location
1.	Eye-washer station	Usually located at lab entrance
2	Emergency shower	Usually located above entrance door
3.	Fire extinguisher	Usually located at lab entrance or inside the firefighting cabinet
4.	"Red" firefighting blanket	Usually located inside the firefighting cabinet
5.	General cutoff switch	Turns off electricity for all outlets (the laboratory lights remain on); located at lab entrance
6.	Main power switch	Turns off all electricity in the lab; located within lab/floor electricity cabinet
7.	Main gas valve	Located outside lab entrance. Every couple of work benches also have main-secondary gas valves marked in yellow
8.	Emergency exits	Familiarize yourself with the location of the laboratory and building exits
9.	First aid kit	Familiarize yourself with the location of the first-aid kit and check that its contents is complete
10.	Lab phone	Familiarize yourself with its location. Dial 2222 in case of an emergency
11.	Smoke detectors	Located <i>within</i> lab ceiling

Responsibilities of the Principle Investigator (PI)

The PI is responsible for the safety and health of all personnel working in his or her lab. The PI may delegate safety duties but remains responsible for ensuring that the delegated safety duties are adequately performed. The PI's responsibilities are:

1. Knowing all applicable safety and health regulations, training and reporting requirements and standard operating procedures associated with chemical safety for regulated substances.
2. Identifying hazardous work or research processes in the lab, determining safe procedures and controls and implementing standard safety procedures.
3. Consulting with the safety and radiation unit regarding the use of higher risk materials or higher risk experimental procedures so that special safety precautions may be administered.
4. Ensuring laboratory or other personnel under his/her supervision have access to and are familiar with all safety regulations.
5. Training all laboratory or other personnel he/she supervises to work safely with hazardous materials.
6. Maintain written laboratory protocols, emphasizing safe handling of hazardous materials.
7. Ensuring the availability of all appropriate personal protective equipment (PPE) (lab coats, gloves, eye protection, etc.) and ensuring the PPE is maintained.
8. Informing facilities personnel, other non-laboratory personnel and any outside contractors of potential laboratory-related hazards when they are required to work in the laboratory environment.
9. Promptly notifying the safety and radiation unit should he/she become aware that work place engineering controls (e.g., fume hoods) and safety equipment (e.g., emergency showers/eyewashes, fire extinguishers, etc.) become non-operational.
10. Promptly reporting accidents and injuries to the safety and radiation unit. Serious injuries **MUST** be reported immediately. Any doubt as to whether an injury is serious should favor reporting.

Responsibilities of the all Personnel working in a Chemical Laboratory (Investigators, Employees, Students)

1. All personnel working with potentially hazardous chemicals are responsible to participate in training seminars on general laboratory safety instructions, following all verbal and written laboratory safety rules, regulations and standard operating procedures required. **Without proper safety training you are not allowed to work in the laboratory.**
2. Developing good personal chemical hygiene habits, including but not limited to, keeping the work areas safe and uncluttered.

3. Planning, reading and understanding the hazards of materials and processes in their laboratory research or other work procedures prior to conducting work. Carefully read the safety sheet (MSDS) of the substances being used.
4. Utilizing appropriate measures to control identified hazards, including consistent and proper use of engineering controls, PPE and administrative controls.
5. Understanding the capabilities and limitations of the PPE.
6. Consulting with PI or lab manager/engineer before using particularly hazardous substances, explosives and other highly hazardous materials or conducting certain higher risk experimental procedures;
7. Properly storing, identifying, handling, and disposing of hazardous waste.
8. Immediately reporting all accidents and unsafe conditions to the PI or lab manager/engineer.
9. Completing all required safety and health training and providing written documentation.
10. Participating in the medical surveillance program, when required.
11. Informing the PI or lab manager/engineer of any work modifications ordered by a physician as a result of medical surveillance, occupational injury or exposure.
12. Notifying in writing and consulting with the PI or lab manager/engineer, in advance, if they intend to significantly deviate from previously reviewed procedures (Note: Significant change may include, but is not limited to, change in the duration, quantity, frequency, temperature or location, increase or change in PPE, and reduction or elimination of engineering controls).

General Safety Regulations in a Lab

Most accidents and/or near-misses occur because of the following main reasons:

- ☒ **Not following standard safety procedures** (taking short-cuts)
- ☒ **Underestimating the dangers associated with chemical reactions** (over confident)
- ☒ **Distractions** (conversations, tiredness, multitasking)

Working in a chemical laboratory requires caution and meticulousness in performance. Familiarize yourself with the lab. Know the location of the safety showers and eyewash stations, fire extinguishers, first aid kit, the chemical spillage kit and the emergency exit routes of the lab and/or building. Most accidents are preventable if safety rules are followed, therefore, act in accordance with the safety instructions.

- **Maintain clean hands.** Sterilization and/or hand washing, preferably with antiseptic chemicals, including alcohol and chlorhexidine or water and soap accompanied by drying using one-time paper towels or the use of modern hand drying machinery.
 - Hand washing or sterilization will be performed following lab work of any kind, including all contact with chemical substances or biological contaminants, before and after going into and out of the toilet and prior to eating and/or drinking and/or putting on makeup and/or smoking (where it is allowed).
- The laboratory should be kept neat, clean and free of materials that are not pertinent to the work.

All items that do not belong in the lab and pose additional hazard should be removed or stored properly.

- **Eating, drinking, chewing gum, putting on makeup and smoking in the laboratory are strictly prohibited.** Eating or entering eating areas with a laboratory coat on is strictly forbidden.
- At the moment the safety unit does not enable working alone in the lab. Make sure that there are at least two people in the lab or someone located next door coupled to notifying security regarding your exact whereabouts (building's name, floor and room number/s). Safelet will soon be introduced by the Safety Unit enabling working alone in the lab. However, **hydrogenations, the use of pyrophorics, corrosives or reactions involving potentially explosive reagents (e.g. iodosobenzene) necessitate are not allowed to be performed outside regular working schedules.**
- If you need to work overnight, contact your supervisor to formulate a work plan. The safety unit may also assist in providing the proper working environment to allow you to work alone. Check before commencing work that your **hood** is in good working condition, i.e.: not cluttered with reaction flasks, chemicals and solvent bottles. Ongoing reactions should be labeled and chemical waste bottles should be closed.
- **Laboratory refrigerators are off-limits.** It is strictly forbidden to store food and beverages in laboratory refrigerators.
- **Centrifuges** pose a grave risk if they rotate at high speed and are not sealed, therefore they must be equipped with a locking apparatus preventing both operating open centrifuges as well as opening the centrifuge's lid while rotating.
- All synthesized chemicals, reactions flasks, solvent pots, etc. should be **clearly labeled**.
- Assume that **all** newly synthesized **chemicals are toxic** and handle them as such. Read MSDS.
 - **It is prohibited to taste or sniff a chemical substance.** If you are required to smell chemical vapors, you must keep the vessel in which the chemical is in away from your nose and wave your hand over the opening so that the substance's vapors will reach your nose in a controlled manner.
- **Do not put a pipette into your mouth.** Using your mouth is a hazard that can cause a toxic substance to be inhaled. Use only a pump aid, such as a syringe, propipette or "Jackie" for this purpose.
- **After removing the substance**, take care to **immediately close the container** from which it was originally taken out of to prevent contamination of the bulk substance, entry or emission of water vapors, emission of volatile substances into the environment or confusion between lids.
- **Do not return a chemical substance to a container.** In case unused chemical substances are left, it is strictly prohibited to return it to the container from which it was originally pumped out of (bottle, box, flask, container). Returning a substance to the container may contaminate the original bulk substance in the container or cause an unwanted chemical reaction in other cases.
- All experimental residual substances must be classified as **chemical waste**.
 - Treat the chemical waste in accordance with the specific substance's handling instructions.
 - Do not pour substances from different classes into the same chemical waste storage container.

- Do not dispose of any hazardous chemicals through the sewer system. These substances might interfere with the biological activity of waste water treatment plants, create fire or explosion hazards, cause structural damage or obstruct flow.
- Research staff and students should **never work alone** on procedures involving hazardous chemicals, pathogens or physical hazards.
- A designated **eye washer** and **emergency showers** operated by a hand chain are installed in every chemical lab. In case of a splash, rinse body part using an excessive amount of water onto body part, clothing or bench, which came in contact with the chemical.
- **Beware of broken glass.** Glass is a hard-breakable material that can be lethal. - When adjusting a glass pipe or thermometer into a stopper, a rubber hose or a cork, use grease and protect your hands with a cloth.
 - Trying to release a cork stuck in a glass vessel could be dangerous. Apply controlled heat or incubation in appropriate solvents by qualified personnel.
 - Do not use a cracked or broken glass vessel.
 - If you break a vessel or encounter a broken vessel, give it to a technician and obtain another one.
 - Broken glassware or any glass waste should always be evacuated into designated sharps bins. Broken glassware, which are thrown into ordinary trash bins, could injure cleaning employees.
 - Always protect your eyes when working with glass.
 - Glassware should always be marked, stating their contents.
 - For procedures which include freezing or freezing and thawing cycles due to thermic expansion work with designated glassware with thick walls. Pay extra attention not to work with cracked glassware.
 - Hot glass looks identical to cold glass.
 - Glassware could explode if exhaust pipes are blocked.
 - Glassware could collapse under negative pressure conditions.
 - When pumping compressed air into a glass vessel in order to dry the vessel, following its washing, the vessel could break. It is therefore recommended to allow glassware to dry on a designated drying apparatus or in an oven.

General

Before commencing a new experiment or chemical reaction please maintain the following guidelines:

1. Arrive mentally prepared: make sure you are well rested and not distracted by other students / conversations / other experiments in the laboratory. Never multitask.
2. Perform a risk assessment prior to commencing your experimental protocol:
 - 2.1 Pinpoint hazards associated with chemicals to be used.
 - 2.2 Make sure you are knowledgeable with the lab's spillage kit, the location of the lab's fire extinguisher, emergency shower and the eyewasher station.

3. Make sure you custom an appropriate experimental set-up, for example:
 - 3.1 Note whether the glassware is undamaged and/or properly clamped.
 - 3.2 Check whether the equipment/glassware is suitable for working with low- or high-temperature or pressure.
 - 3.3 In case your reaction might produce excess pressure, assure the existence of an outlet (oil/mercury bubbler).
 - 3.4 All reactions necessitating working in a closed vessel (e.g. pressure tube or Schlenk tube) oblige calculating the maximum pressure, thereby making sure the glassware is indeed resistant to handle such pressures.
 - 3.5 Reactions under pressure, reduced pressures as well, should always be performed behind a blast shield. Glassware can always fail unannounced under high- or low-pressures.
 - 3.6 Position and clamp the reaction apparatus thoughtfully.
 - 3.7 Minimize shuttling of the set-up apparatus.
 - 3.8 Each reaction should be labeled, specifically reactions which are ongoing. Always think of your fellow students' safety.
4. Follow to the letter the experimental protocol. Read SDS carefully and make sure you are knowledgeable regarding products that are to be formed during the reaction (including gasses) and their associated hazards. Take extra care to follow the special safety precautions guidelines of each protocol section.
 - 4.1 Combine reagents in the appropriate order.
 - 4.2 Never add solids to hot liquids.
 - 4.3 Never add water to acids, only vise versa: acids should always be added to water.
5. Take your time to perform the chemical reaction and do not take short-cuts. Severe accidents have taken place when students took grave initiatives to "save time".

Personal Protective Equipment (PPE)

PPE includes equipment accessories the employee must wear to mitigate, at a minimum, exposure to hazardous materials. Nevertheless, PPE does not eliminate safety risks, but rather assists in protection, lowering potential exposure. In some cases, additional, or more protective, equipment must be used.

- It is mandatory to wear a **long-sleeved lab coat** and **closed-toed shoes** when working in a chemical and/or biological laboratory. Do not wear sandals or open shoes. Use Flame resistant laboratory coats for high hazard materials, pyrophorics, and flammables.
- **Gloves** protect against skin absorption of chemicals, chemical burns, thermal burns, lacerations, chemicals of unknown toxicity, corrosives rough or sharp-edged objects, and very hot or cryogenic liquid exposure. The two most common gloves for laboratory use are:
 - Latex gloves - supply high sensitivity, enabling maximum control of touch and gentle motor skills. However, latex may cause sensitivity or become an allergen. Latex exposure symptoms include skin rash and inflammation, respiratory irritation, asthma and shock.

- Nitrile or neoprene gloves which do not contain the latex protein – they are more durable to shearing and chemicals, but they can cause oxidation of silver and highly-reactive metals, which can react with sulphur.
- Gloves degrade over time, so they should be replaced as necessary to ensure adequate protection.

Butyl	Offers the highest resistance to permeation by most gases and water vapor. Especially suitable for use with esters and ketones.
Neoprene	Provides moderate abrasion resistance but good tensile strength and heat resistance. Compatible with many acids, caustics and oils.
Nitrile	Excellent general duty glove. Provides protection from a wide variety of solvents, oils, petroleum products and some corrosives. Excellent resistance to cuts, snags, punctures and abrasions.
PVC	Provides excellent abrasion resistance and protection from most fats, acids, and petroleum hydrocarbons.
PVA	Highly impermeable to gases. Excellent protection from aromatic and chlorinated solvents. Cannot be used in water or water-based solutions.
Viton	Exceptional resistance to chlorinated and aromatic solvents. Good resistance to cuts and abrasions.
Silver Shield	Resists a wide variety of toxic and hazardous chemicals. Provides the highest level of overall chemical resistance.
Natural rubber	Provides flexibility and resistance to a wide variety of acids, caustics, salts, detergents and alcohols.

- Most SDS recommend the most protective glove material in their PPE section.
- Gloves should be removed avoiding skin contact with the exterior of the glove and possible contamination.
- When handling acids, bases or other corrosive solvent mixtures, elbow thick rubber gloves should be worn. Underneath rubber gloves one should always wear nitrile gloves in case the outer rubber gloves are cut.
- Remove one glove when entering an elevator and put its buttons with the ungloved hand. Similarly upon opening and closing door handles.
- Remove gloves before operating computers.

- Safety glasses provide the basic protection against chemical splashes, sparks, or glass shards. Safety goggles should form a seal with the face, completely isolating the eyes from the hazard. Specifically, protective goggles or a face mask must always be worn while using acids and/or glues and/or other chemical substances. If you are required to wear prescription glasses, goggles should be worn over them. **Refrain from wearing eye contacts.** Their use may cause damage if vapor from a foreign substance is trapped between the lens and the eye, specifically when working with volatile and toxic chemicals, since an eye contact could interfere in case of an accident with a liquid, which will necessitate the use of a designated eye washer device.

- Eye and Face Protection PPE options:

Safety Glasses	Safety frames constructed of metal or plastic and impact-resistant lenses. Side protection is required. [ANSI standard Z87.1]
Chemical Splash Goggles	Tight fitting eye protection which completely covers eyes, eye sockets and facial area surrounding eyes. Provides protection from impact, dust and splashes. [ANSI standard Z87.1]
Dust Goggles	Tight fitting eye protection designed to resist passage of large particles through goggles (direct ventilated goggles) [ANSI standard Z87.1].
Fluid Resistant Shields	Fluid resistant or impervious and provide splash protection from biological material, such as human or non-human primate body fluids.
Face Shields	Extend from eyebrows to below the chin and across the head's width. Face shields protect against potential splashes or sprays of hazardous liquids. When worn for protection against UV, must be specifically designed to protect the face and eyes from hazardous radiation. When used for chemical protection or UV protection, must comply with ANSI standard Z87.1.
Laser Eyewear	Required for Class 3 and 4 laser use, where irradiation of the eye is possible. Such eyewear should be used only at the wavelength and energy/power for which it is intended.

- Always wear **closed-toe shoes** inside buildings where chemicals are stored or used. Do not wear perforated shoes, sandals or cloth sneakers in laboratories or where mechanical work is conducted. These shoes offer no barrier against chemical and physical hazards. Chemical resistant shoes or boots may be

used to avoid possible exposure to corrosive chemical or large quantities of solvents or water that might penetrate normal footwear (e.g., during spill cleanup). Leather shoes tend to absorb chemicals and may have to be discarded if contaminated with a hazardous material.

- Confine **long hair** and **loose clothing**.
- While working in noisy conditions, always wear **earplugs or hearing protectors** during your work or presence in the noisy area.

In addition to all PPE mentioned herein, one should always plan beforehand to match the optimal PPE to the chemical reactions performed. For example, when working with pyrophoric materials, it is not advisable to wear clothing made from nylon. Think Safety! PPE should always be kept clean.

The equipment should be inspected prior to use and fit and worn properly. If the PPE becomes contaminated or damaged, it should be cleaned or replaced.

Fume Hoods

Fume hoods are the most commonly used exhaust systems on campus. Other methods include vented enclosures for large pieces of equipment, biological hoods and glove boxes. Some systems are equipped with air cleaning devices (HEPA filters or carbon absorbers). Exhaust from fume hoods are designed to terminate at least 3 meters above the roof deck. A properly operating fume hood can reduce or eliminate gases from volatile liquids, dusts and other contaminants.

- It is advisable to use a fume hood when working with all hazardous substances.
- Fume hoods should not be used for work involving hazardous substances unless they have a certification label that confirms annual evaluation, checking the fume hood air flow velocity. Each fume hood should have a current calibration sticker and a marker indicating the highest sash height to be used when working with hazardous materials.
- Always keep hazardous chemicals > 16 cm behind the sash.
- Never put your head inside an operating hood. The plane of the sash is the barrier between contaminated and uncontaminated air.
- Work with the hood sash in the lowest practical position. The sash acts as a physical barrier in the event of an accident. Keep the sash closed when not conducting work in the hood.
- Do not clutter your hood with unnecessary bottles or equipment. Keep it clean and clear. Only materials actively in use should be in the hood. When hazardous materials are in a fume hood, but it is not under active use (during an unattended reaction or experiment), the sash should be closed.
- Keep hood closed when you are not working in the hood.
- When an uncontrollable fire commences in the hood, close the sash of the hood to contain it.



Pictograms



Health Hazard: A cancer-causing agent (carcinogen) or substance with respiratory, reproductive or organ toxicity, which may causes damage over time.



Flame: Flammable materials or substances liable to self ignite when exposed to water or air (pyrophoric), or which emit flammable gas.



Exclamation Mark: An immediate skin, eye or respiratory tract irritant, or narcotic.



Gas Cylinder: Gases stored under pressure, such as ammonia or liquid nitrogen.



Corrosion: Materials causing skin corrosion/burns or eye damage upon contact or corrosive to metals.



Exploding Bomb: Explosives, including organic peroxides and highly unstable materials at risk of exploding even without exposure to air (self-reactives).



Oxidizers: Chemicals that facilitate burning or make fires burn hotter and longer.



Acute Toxicity: Substances, such as poisons and highly concentrated acids, which have an immediate and severe toxic effect.

Lab Safety Equipment

Fire Extinguishers

- All laboratories working with combustible or flammable chemicals must be outfitted with fire extinguishers.



- All fire extinguishers should be mounted on a wall in an area free of clutter or stored in a fire extinguisher cabinet.
- Research personnel should be familiar with the location and use of the extinguishers in their lab.
- Laboratory personnel are not required to extinguish fires that occur in their work areas and unless it is a small fire (for example, a small trash can sized fire) or in case appropriate training has been received.
- Any use of the fire extinguisher, the PI or lab manager/engineer must immediately report the incident to the safety and radiation unit.



Safety Showers and Eyewash Stations

- All laboratories using hazardous chemicals must have immediate access to safety showers with eye wash stations.
- Access must be available in 10 seconds or less.
- No objects should be stored or left within this distance of the safety shower.
- In the event of an emergency, individuals using the safety shower should be assisted by an uninjured person to aid in decontamination and should be encouraged to stay in the safety shower for 15 minutes to remove all hazardous material.
- **Fire Doors**

Fire doors are an integral of the building design.

- These doors are an important element of the fire containment system and should remain closed unless they are on a magnetic self-closing or other automated self-closing system.

Chemical Spills

Chemical spills are quite frequent in the laboratory and can usually be handled without any significant hazards. Various precautions need to be taken depending on the nature of the spilled chemical (toxicity, flammability, volatility, etc).

- If skin / eyes have been exposed to a chemical or to a solvent - rinse affected area with copious amounts of water for at least 15 minutes.
- If case of exposure to a hydrofluoric acid (HF) containing solution, rinsing should only be for five (5) minutes followed by application of Calcium Gluconate Gel to the affected area, followed by medical treatment.
- In case of eye contact - rinse with copious amount of water and monitor affected area. See medical attention.
- In case clothing has been contaminated - remove the contaminated clothing piece immediately. Rinse affected area with copious amounts of water. If necessary, see medical attention.
- In case of a chemical spill bearing a highly toxic character (ammonia, osmium, radioisotopes, ethers, strong acids, nitro compounds, hydrofluoric acid, halogens, cyanides, nitriles, aromatic amines) outside of the hood - close the sash of the hood. Most volatile materials will dissipate over time or can be cleaned up by using absorption pads. In case of hydrofluoric acid and cyanides, qualified personnel should be notified immediately.
- In case of a chemical spill bearing a highly toxic character (ammonia, osmium, radioisotopes, ethers, strong acids, nitro compounds, hydrofluoric acid, halogens, cyanides, nitriles, aromatic amines) outside of the hood - do not attempt to clean the spill yourself. Notify co-workers and evacuate area immediately. Close the doors of the laboratory and post signs on the laboratory doors notifying danger.



Chemical Waste

Improper waste disposal can also lead to serious and frequently unexpected accidents.

- No chemical waste can be disposed of *via* the sewage system.
 - Exceptions are unused dilute aqueous sodium or potassium hydroxide buffers, unused aqueous hydrochloric or sulfuric acid buffers.
- Before adding waste to a chemical waste container, make sure that your chemicals are not incompatible and that reactive chemicals have been properly quenched. Combining incompatible waste or using an incompatible container could cause rupturing of containers and explosions.
- Chemical waste at the Technion is separated into three (3) principle classes:
 1. Organic solvents - All solvents and (in)organic chemicals. Most of the chemical waste generated in the laboratory can be added to this container. Never add oxidizers (such as hydrogen peroxide) to the organic waste. This could result in a fire or an explosion. Clearly indicate on the safety label which chemicals are present .
 2. Acids.
 3. Solids - Broken glass, vials and pipettes are collected in an appropriately labeled container; used needles are collected in another designated (red with a yellow opening lid) container.
 4. Oxidizers.
 5. Nitric acid and Piranha solutions are collected separately. These mixtures of acids produce strongly oxidizing solutions. Do not keep them in the hood for extended periods of time, as they will corrode the metal-framework in the fume hood. Never ever mix them with even trace amounts of organics as this can result in explosions. Use glass bottles for collecting the chemical waste. Do not mix these acids together. Make sure the glass bottles do not contain residual organic materials. Do not cap the bottles as their decomposition produces gaseous vapor, which could lead to an explosion. These bottles should be kept in or underneath the fume hood, properly labeled and covered with parafilm.
 6. Always think before disposing waste in a container! Caution should be given to peroxide forming chemicals (PFCs), as they can be highly explosive.

Incompatibility chart of prevalent lab chemical

Chemical	Incompatible with
Acetic Acid	Chromic Acid, nitric acid, hydroxyl-containing compounds, ethylene glycol, perchloric acid, peroxides, and permanganates.
Acetone	Bromine, chlorine, nitric acid, sulfuric acid, and hydrogen peroxide.
Acetylene	Bromine, chlorine, copper, mercury, fluorine, iodine, and silver.
Alkaline and Alkaline Earth Metals such as calcium, lithium, magnesium, sodium, potassium, powdered aluminum	Carbon dioxide, carbon tetrachloride and other chlorinated hydrocarbons, water, Bromine, chlorine, fluorine, and iodine. Do not use CO2, water or dry chemical extinguishers. Use Class D extinguisher (e.g., Met-L-X) or dry sand.
Aluminum and its Alloys (especially powders)	Acid or alkaline solutions, ammonium persulfate and water, chlorates, chlorinated compounds, nitrates, and organic compounds in nitrate/nitrate salt baths.
Ammonia (anhydrous)	Bromine, chlorine, calcium hypochlorite, hydrofluoric acid, iodine, mercury, and silver.
Ammonium Nitrate	Acids, metal powders, flammable liquids, chlorates, nitrates, sulfur and finely divided organics or other combustibles.
Aniline	Hydrogen peroxide or nitric acid.
Bromine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, finely divided metals, sodium carbide, turpentine.

Calcium Oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents.
Caustic (soda)	Acids (organic and inorganic).
Chlorates or Perchlorates	Acids, aluminum, ammonium salts, cyanides, phosphorous, metal powders, oxidizable organics or other combustibles, sugar, sulfides, and sulfur.
Chlorine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, finely divided metals, sodium carbide, turpentine.
Chlorine Dioxide	Ammonia, methane, phosphine, hydrogen sulfide.
Chromic Acid	Acetic acid, naphthalene, camphor, alcohol, glycerine, turpentine and other flammable liquids.
Copper	Acetylene, hydrogen peroxide.
Cumene Hydroperoxide	Acids
Cyanides	Acids
Flammable Liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, bromine, chlorine, fluorine, iodine.
Fluorine	Isolate from everything.

Hydrazine	Hydrogen peroxide, nitric acid, and other oxidizing agents.
Hydrocarbons	Bromine, chlorine, chromic acid, fluorine, hydrogen peroxide, and sodium peroxide.
Hydrocyanic Acid	Nitric acid, alkali.
Hydrofluoric Acid	Ammonia, aqueous or anhydrous.
Hydrogen Peroxide (anhydrous)	Chromium, copper, iron, most metals or their salts, aniline, any flammable liquids, combustible materials, nitromethane, and all other organic material.
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases.
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen.
Mercury	Acetylene, alkali metals, ammonia, fulminic acid, nitric acid with ethanol, hydrogen, oxalic acid.
Nitrates	Combustible materials, esters, phosphorous, sodium acetate, stannous chloride, water, zinc powder.
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, flammable gases and liquids, hydrocyanic acid, hydrogen sulfide and nitratable substances.
Nitrites	Potassium or sodium cyanide.

Nitroparaffins	Inorganic bases, amines.
Oxalic acid	Silver, mercury, and their salts.
Oxygen (liquid or enriched air)	Flammable gases, liquids, or solids such as acetone, acetylene, grease, hydrogen, oils, phosphorous.
Perchloric Acid	Acetic anhydride, alcohols, bismuth and its alloys, paper, wood, grease, oils or any organic materials and reducing agents.
Peroxides (organic)	Acid (inorganic or organic). Also avoid friction and store cold.
Phosphorus (white)	Air, oxygen.
Phosphorus pentoxide	Alcohols, strong bases, water.
Potassium	Air (moisture and/or oxygen) or water, carbon tetrachloride, carbon dioxide.
Potassium Chlorate	Sulfuric and other acids.
Potassium Perchlorate	Acids.
Potassium Permanganate	Benzaldehyde, ethylene glycol, glycerol, sulfuric acid.
Silver and silver salts	Acetylene, oxalic acid, tartaric acid, fulminic acid, ammonium compounds.
Sodium	See Alkali Metals
Sodium Chlorate	Acids, ammonium salts, oxidizable materials and sulfur.

Sodium Nitrite	Ammonia compounds, ammonium nitrate, or other ammonium salts.
Sodium Peroxide	Any oxidizable substances, such as ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerol, ethylene glycol, ethyl acetate, methyl acetate, furfural, etc.
Sulfides	Acids.
Sulfur	Any oxidizing materials.
Sulfuric Acid	Chlorates, perchlorates, permanganates, compounds with light metals such as sodium, lithium, and potassium.
Water	Acetyl chloride, alkaline and alkaline earth metals, their hydrides and oxides, barium peroxide, carbides, chromic acid, phosphorous oxychloride, phosphorous pentachloride, phosphorous pentoxide, sulfuric acid, sulfur trioxide.

Specific Chemical Reactions and Associated Safety Guidelines

- Uncontrolled **chemical reactions** are usually exothermic. i.e.: they produce heat and release energy.



An exothermic chemical reaction could, under specific circumstances, go out of hand, spraying hot liquids or dangerous fumes. It is advisable to add the necessary components - in an organized order and in exact quantities - to prevent a radical temperature elevation. Only following a considerable cooling time interval another dose could be safely added to the reaction, for example: adding powder to a

liquid, which is on the verge of its boiling point, could result in heavy production of fumes, spillage of the liquid from the vessel and pressure build-up. To avoid the latter, small doses of the powder can be added while the reaction is still cool.

- **Do not under any circumstances pour water into an acid (or alkaline).** When preparing a diluted acid or alkaline solution, take care to always slowly pour the acid or alkaline into the water while stirring (not vice versa).
 - Preparation of a solution must be carried out in a fume hood, working slowly and stirring the solution. The reaction during this mixing is exothermic (emits heat), for example: dilution of sulfuric acid in water is liable to cause the solution to boil, thus if water is poured into the acid, the hot solution will splash, posing a great risk.
 - Never direct glass tubes in which chemical reactions or heating reactions are being performed towards one's face or towards other employees.
 - Incorrect marking on containers and packages could lead to improper chemical use, which – in turn – will lead to an uncontrolled chemical reaction between chemicals. Every package and/or container must be marked with a clear and readable sticker.
 - The chemical's labels must always be read prior to use.
 - Do not conduct an experiment without obtaining permission from your supervisor. Never work in a laboratory alone unless authorized to do so by the safety and radiation unit.
 - Make sure to read the labels on the bottles and chemical storage containers (including chemical waste) to ensure that the substance conforms precisely to the requirements.
- **Volatile** substances must be handled with care. An explosion could occur as a result of working with volatile or unstable compounds due to touch, chafing, abrasion or heating.
- Therefore, the experimental setup should be situated in a closed compartment or chemical hood, protecting both the employee as well as his/hers surroundings. Upon opening the closed compartment or lifting the glass of the hood one must be protected by a polycarbonate face mask, especially when performing nitrations.
 - Automatic and remote-controlled equipment are always preferable.
 - Distillation of certain organic compounds, such as ethyl ether – could, in time, produce peroxides (=compounds high in oxygen), which could cause an explosion.
 - Even fumes released from volatile liquids, which are stored in a refrigerator in non-hermetic vessels, could explode or cause fire. Therefore, volatile liquids will be stored inside a refrigerator devoid of internal lighting and of which thermostat is located outside the refrigeration space.
 - Electrical components around the laboratory should be explosion-proof.
-

- Chemical burns are caused because of contact with certain **corrosives**, such as strong acids (sulfuric, nitric, hydrochloric and hydrofluoric acids), strong bases (sodium hydroxide, potassium hydroxide and ammonium hydroxide), dehydrating agents (phosphorus pentoxide and calcium oxide), oxidizing agents (chlorine and bromine). Corrosive substances cause destruction of, or alterations in, living tissue by chemical action at the site of contact.



- Spillage or splashing on an employee's clothing could result from manipulation of corrosives between vessels, therefore PPE should be used: neoprene or other gloves according to the corrosive's identity, sealed goggles or a face-mask, a manual pump.
 - Direct glassware heating above a hot flame could rupture the glassware and cause spillage. To avoid heating by flame at a high and non-homogenous temperature place a metal net to demarcate between the glassware and the flame.
 - Heating of a liquid-containing tube will be performed above a not-too-hot-a-flame while shaking the tube side to side to ensure homogenous temperature dispersion in the tube.
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-



- Pay extra attention when working with **flammable** chemicals. Flammable liquids include chemicals which have a flashpoint of less than 37.8°C. Flashpoint is the minimum temperature of a liquid at which it gives off sufficient vapor to form an ignitable mixture with air. Liquids with a flash point near room temperature can be ignited very easily during use.

- Pouring flammable liquids can generate static electricity, related to the humidity levels in the area. Cold, dry atmospheres are more likely to facilitate static electricity. Bonding or using ground straps for metallic or non-metallic containers can prevent static generation.

- Whenever possible use plastic or metal containers.
- When working with open containers, use a laboratory fume hood to control the accumulation of flammable vapor.
- Do not use an open flame to heat flammable liquids. Steam baths, salt and sand baths, oil and wax baths, heating mantles and hot air or nitrogen baths are preferable.
- Minimize the production of vapors.
- Simultaneous use of volatile and oxidative chemicals, which are in proximity in the laboratory, could result in combustion; therefore, try to avoid from using volatile and oxidative substances simultaneously. In case it is necessary to use both – work in small doses and avoid heating them.
- Do not use burners around flammable-volatile liquids. Heating such liquids should be performed on a heating plate in a water or oil medium or using designated electrical pillows.
- Using electrical appliances, which produce sparks, could also cause fires. It is mandatory to keep any appliance away from a location at which flammable gases or liquids are being used. The appliances should also be equipped with warning lights to mark the appliance's operation.
- The use of compressed air engines is recommended. Any appliance flaw or heating of wires should be reported to maintenance.
- Distillation of a flammable liquid is exothermic. Heat must therefore be evacuated from the system by a condensation refrigerator or else the liquid fumes will be exhausted and might combust. The water pipeline to the condensation refrigerator must be closely monitored. Installation of an automatic switch is recommended.
- Boiling of a flammable liquid inside a glass flask or a designated glass bulb is not homogenous, therefore the liquid could splash. To ensure a stable boiling pace, several glass spherules or ceramic shards should be placed inside the flask or the bulb.
- Fumes of a flammable liquid, which was accidentally spilled, disperse rapidly and pose a major fire threat. In that case, all open-fire or spark-generating machinery should be shut down. The spilled liquid should be collected using paper towels or a liquid-absorbing powder.
- Certain chemical compounds, such as Sulphur, spontaneously combust in air. Handling of these compounds will be executed in an inert environment (for example: in nitrogen).

Pyrophoric chemicals spontaneously ignite in air. No source of ignition (spark) is needed as they spontaneously react when exposed to oxygen. Silane is an example of a pyrophoric gas. Working with pyrophoric materials, such as alkyl aluminum, zinc or lithium reagents, metal hydrides, alkali metals and others, necessitates the use of appropriate inert atmosphere techniques, i.e. glovebox or Schlenk line techniques.

- Prior to commencing work with pyrophoric materials, always make sure you are familiar with the specific pyrophoric reagent's SDS.

- Prior to commencing work with pyrophoric materials, always make sure you are familiar with emergency measures, as pyrophoric reagents react very quickly, leaving almost no reaction time.
- Note that most pyrophoric reagents will react with the contents of common fire extinguishers. Sand is an effective measure for containing fires involving pyrophoric materials.
- PPE should include: a fire-resistant lab coat, long pants made of less-flammable materials, such as jeans, safety goggles, impermeable gloves and closed shoes are worn. Tuck long hair.
- Inspect all glassware before use: the glassware should be thoroughly dried and purged with an inert gas (e.g. nitrogen or argon). Note that some pyrophoric reagents will react exothermically with nitrogen.
- Before commencing pyrophoric reaction, always be instructed by an experienced researcher on how to safely perform the reactions. The experienced researcher should also be present in subsequent times until the unexperienced employee is confident enough to perform the reactions independently.
- Remove all other flammable materials from your working area, including solvent bottles, unused chemicals, or other combustible materials.
- When working in the hood, make sure the sash is lowered as much as possible.
- Never work alone when using pyrophoric reagents. Always have a co-worker in close proximity when performing chemical reactions involving pyrophoric reagents.
- Use Hamilton® gas-tight syringes only for transferring small quantities of pyrophoric reagents. Do not fill syringes more than 75% of their designated maximum volume. Do not transfer more than 15 mL at once.
- Do not use excess-pressure to fill syringes with pyrophoric reagents. Use an oil bubbler to equalize pressure between the vessel containing the pyrophoric reagent and the Schlenk line. The oil bubbler also prevents back-flow of oxygen into the experimental set-up and provides a low-pressure nitrogen inlet into the reagent bottle.
- Use double-tipped needles for cannula transfer of pyrophoric reagents.
- Maintain the correct temperature (mostly between $-78\text{ }^{\circ}\text{C}$ and $-100\text{ }^{\circ}\text{C}$) when working with pyrophoric reagents. Avoid liquid nitrogen as a coolant.
- Upon completion of work with pyrophoric reagents, small amounts can be quenched by slowly adding the pyrophoric residues to dry hexane inside the hood. In turn, the hexane solution can slowly be quenched by adding iso-propanol.
- Empty pyrophoric reagents bottles containing septa should be quenched by piercing the septa with a needle and leaving the bottle for approximately one week in the back of the hood. After a week, remove septa and carefully add isopropanol. Discard liquid as basic waste.

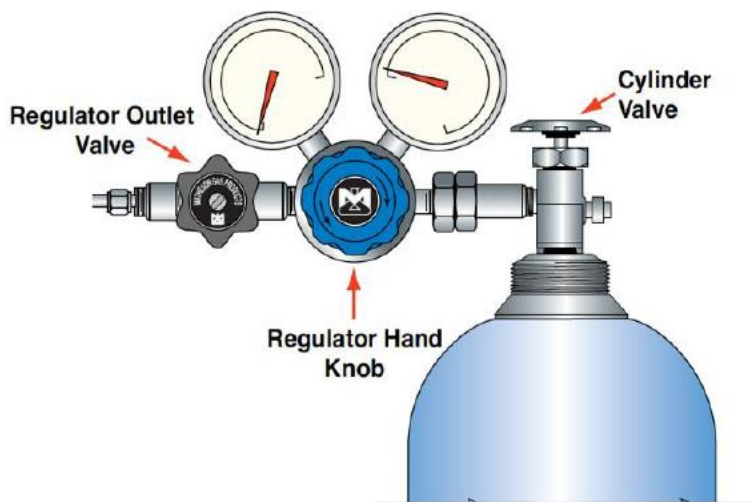
- In case a small containable spill in the hood remove all flammable materials from the area. If needed use a fire extinguisher in line with SDS instructions. When possible, slowly quench spill with isopropanol.
- **Hydrogenation** reactions can potentially pose an extreme fire and explosion hazard due to their involvement of hydrogen gas (H_2) and/or the use of flammable metals or solvents or pyrophorics.
- Always read SDS carefully prior to commencing hydrogenations.
 - Be knowledgeable of all safety measures in case of emergency.
 - Most of the reagents will react with the contents of common fire extinguishers. Sand is very effective, therefore keep a bucket of sand close by to immediately quench accidental fires
 - Before commencing hydrogenations, always be instructed by an experienced researcher on how to safely perform the reactions. The experienced researcher should also be present in subsequent times until the unexperienced employee is confident enough to perform the reactions independently.
 - Never work alone when performing hydrogenation reactions. Always have a co-worker near when performing chemical reactions involving hydrogen.
 - When performing hydrogenations always use a glovebox and other inert atmosphere techniques.
 - Make sure all heat sources, open flames, electrical sources or other incompatible chemicals are removed from the hood and not allowed in proximity to the hydrogen source.
 - Make sure that you do not carry any static electricity!
 - Make sure your experimental set-up glassware is intact.
 - Never exchange system set-up equipment used in hydrogenations.
 - Prior to introducing the hydrogen into the reaction vessel, make sure that the contents of the vessel have been properly degassed and any advantageous amounts of oxygen have been removed.
 - Hydrogenation catalysts should always be kept moist using either solvents or water (procedure-dependent). Dry catalysts are most-likely pyrophoric.
 - Hydrogenation catalysts should be kept moist also upon filtering the reaction mixture to remove the heterogenous catalysts. Use low vacuum. Notice any sparks when filtering.
 - Upon completion add water to avoid fires. Adding solvent to a sparking catalysts cake will cause a flash fire.
 - Dispose of residual catalysts ASAP. Never throw the filtering pads into the trash due to fire hazard.
 - Prior to opening the vessel in which the reaction took place to the atmosphere upon hydrogenation completion, degas vessel's contents to assure all hydrogen gas has been removed. Absorbed hydrogen on Pd/C can easily ignite when dry and exposed to air.
 - In case of fire or an explosion involving hydrogen gas, when possible, close the main valve of the hydrogen cylinder.
-

➤ **Compressed gasses** are used in the lab routinely. A compressed gas is any flammable or non-flammable material or mixture thereof, having a pressure exceeding 3 bar (43 psi) at 21°C in the cylinder. The most prevalent gasses used in labs are nitrogen, argon, oxygen, and hydrogen gas.

- Always wear appropriate PPE, including a lab coat, safety goggles, closed-toed shoes and nitrile gloves. Always wear safety goggles when handling low-pressure or high-pressure vessels, especially when using low/high-pressure NMR tubes, even outside of the lab. Glassware can unexpectedly fail under low/high pressure causing glass fragments to shatter.
- Safety shoes are required when shuttling compressed gas cylinders.
- Make sure the gas cylinders are appropriately labeled.
- Do not store gas cylinders in the lab.
- Do not roll cylinders or transport gas cylinders horizontally.
- Compressed gas cylinders should be stored and transported with their safety cap in place.
- Gas cylinders should be harnessed to the wall with double chains



- Gas regulators and detectors should always be installed. Make sure that the gas cylinders match the type of regulator. Make sure regulators are leak-tested when installed (usually a soapy solution will work fine). Never use water, grease or oils on oxygen regulators as they can cause an explosion upon contact with oxygen.
- Keep oxygen gas cylinders at least 5 meters away from any source of heat, flames, sparks and/or other ignition sources, explosive gas mixtures (such as hydrogen) included.
- Be familiar with the SDS of the compressed gasses you are about to use.



A general set-up of a gas regulator

- ✚ **Carbon Monoxide – CO** - Carbon monoxide (CO) poses a severe health risk since it is colorless and odorless and is lethal in even small concentrations.
 - Inexperienced employees and/or students are not allowed to use carbon monoxide. Qualified personnel should first demonstrate how to properly handle carbon monoxide in chemical reactions and be present in subsequent times until confident the employee and/or student can handle carbon monoxide independently and safely.
 - Never work alone when using CO. Always have a co-worker nearby.
 - Never use CO without using a portable CO detector. If the detector's alarm goes off or CO is accidentally released, stop work ASAP. If possible, close the valve of the CO-cylinder and ventilate area. Do not enter area until the alarm ceases or when allowed by qualified personnel.
 - Make sure all heat sources, open flames, electrical sources or other incompatible chemicals are removed from the hood.
 - Make sure your experimental set-up glassware is intact.
 - Use CO at low pressure or atmospheric pressures only.
 - Mount the CO cylinder in the hood securely in a secondary container.
 - Upon reaction completion, degas the reaction vessel prior to opening the vessel to the atmosphere.
 - If CO exposure symptoms are present, immediately move to fresh air and notify emergency services.

➤ Every laboratory contains chemicals at various toxicity levels, for example: methanol and tetrachloride carbon. The use of such chemicals in the open air causes lung or skin exposure. Chemicals at various

states - solid / liquid / gas – produce a relatively high vapor pressure and are **poisonous** upon inhalation (respiratory exposure). Exposure by ingestion is very rare in chemical laboratories.

- Every experiment that emits poisonous or odorous gases must be carried out in a fume hood. Remember: if the fume hood door is open the effectiveness of the gas containment is lessened.
 - Handling of poisonous or carcinogenic chemicals will be performed inside a fume hood using gloves, forceps etc.
 - Heating or drying certain chemicals could also emit poisonous vapor, therefore, the drying heater should be equipped with a vapor extracting device, pumping the poisonous vapor outside the laboratory building.
 - Washing dirty glassware using organic solvents, such as: acetone, alcohol or other volatile hydrocarbon solvents will emit poisonous vapor into the laboratory atmosphere, therefore it is recommended to wash lab glassware at a designated laboratory dishwasher. Cleaning of glassware using solvents will only be performed inside a well-ventilated fume hood.
 - Shaking of glass vessels containing volatile substances lead to breakage and, in turn, the release of poisonous vapors.
 - Chemical spillage could contaminate the entire lab atmosphere. Open lab windows in case the contaminant's concentration is low. In case the contaminant's concentration is high – evacuate the lab area ASAP and inform the safety unit. Return to the lab will only be enabled following environmental monitoring and verification by the safety and radiation unit.
 - The poisonous effect of gasses could be exacerbated in a small and closed atmosphere, such as an elevator. Chemicals packaged in glass containers should only be shaken upon storage in a protective package.
 - Shuttling chemicals in elevators will only be performed in cargo elevators (not in passenger elevators).
 - Make sure the container is sealed upon finishing usage of poisonous-vapor emitting chemicals, even after the container is empty.
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- There are **Bunsen burners** of different sizes and flame strengths (flame temperature: 600°C-1,000°C).
- After igniting the flame, check for gas odor: if you smell gas, turn off the flame and immediately notify the person responsible and the engineer or technician (cooking gas has an odorous substance added synthetically to warn about a leak).
 - Check whether the gas pipeline is intact and that it is not close to a heat source.
 - Replace the rubber hose once every two years.
 - Heating by flame must be carried out slowly and cautiously.

- Not every glass vessel can be used for flame heating. The equipment permitted for heating are a chemical cup, Erlenmeyer flask or ceramic crucible.
 - Keep away any flammable materials, solvents, gasses and chemicals, especially if you work inside the fume hood. The hood should also be well ventilated of solvent vapors.
 - Do not leave the lit burner unattended!
 - Never use open flames to perform solid-state reactions at elevated temperatures.
 - When the work with the burner is completed, turn off the flame in the following sequence: Shut the burner valve > make sure the flame extinguished > close the valve to which the rubber hose is connected > close main valve at the end of the workday.
-

➤ Controlled **heating**. Any heating of a system or container must be carried out in a controlled and careful way.

- When heating a material in a test tube, verify that the test tube opening is not facing you or your colleagues. **The use of a sealed vessel when heating is absolutely prohibited**. Heating a closed system builds pressure that can cause the container to explode.
- Many experiments are carried out at different temperatures. It is preferable to use an **electric plate** rather than a gas burner to heat flammable materials.
- Take care to heat toxic and corrosive substances in a fume hood.
- Keep away any flammable materials.
- Do not leave the heating system unattended! Do not leave heating liquids unsupervised.
- Keep unrelated experimental materials and equipment away from the electric plate.
- Take care that the electric cord does not heat up or get damaged.
- If you wish to check whether the plate is heating up, touch the heating source with the back of your fingers, not the fingertips.
- Never heat a solvent more than 5 °C above its boiling point in a closed vessel. Always calculate the maximum pressure that a solvent exerts on a closed vessel under heating conditions (Clausius Clapeyron Equation). If a mixture of solvents is used, assume the pressure exerted by the lowest boiling solvent as the maximum pressure. Make sure the glassware and set-up can support the calculated maximum pressure. Do not exceed the recommended pressure stated by the manufacturer and inspect the pressure vessel for faults before usage.
- If the solution is to be heated, only a glass container should be used.
- If using a hydrofluoric acid containing solution, use a plastic or Teflon container, since the chemical will attack glass.
- When the experiment is finished, turn off the power switch.
- Remove the plug from the wall socket at the end of the workday.

- Heat burns could result from hot or boiling water, oil, melted metal or an open flame.
 - Dipping of glassware containing volatile liquids inside a heating bath could rupture the glass vessels and disperse chemicals, therefore work must only be performed with intact glassware crack-free, sustainable of thermal shock. The vessels will be dipped inside the heating bath gradually.
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➤ **Cryogenic** liquids are defined as having a boiling point that is below $-73\text{ }^{\circ}\text{C}$. These liquids and their vapors are usually unreactive, colorless and odorless. They're usually used in laboratories to produce extremely low temperatures (below -153°C), such as liquid nitrogen (b.p.: $-196\text{ }^{\circ}\text{C}$). Although dry ice or carbon dioxide is solid and therefore is not considered as a cryogenic liquid, it is immediately sublimated (at -78°C) to carbon dioxide gas. Dry ice is prevalently used to shuttle samples, grind materials and perform experimental procedures with. Therefore, dry ice, as well as liquid nitrogen, pose a potential laboratory risk.

- When working with cryogenics one should always protect one's hands in order not to touch frozen surfaces and avoid a frost bite. Cryogenic gloves are recommended. Never touch liquid nitrogen or dry ice with your bare hands. Use gloves which can be easily removed. Do not wear nitrile gloves when handling cryogenic liquids as they will freeze unto your skin immediately upon contact.
- Never touch materials, metals especially, which have been exposed to cryogenic liquids. Handle them with forceps, tweezers or tongs, preferably waiting until they have reached room temperature before handling them. Dry ice, for example, should only be handled using forceps. Never use a heat gun or other methods to thaw liquids or metals that have been cooled down using cryogenic liquids. Large temperature differences might lead to cracking or metal fatigue.
- In case a glass vessel should be cooled down, dip the vessel slowly and gradually inside the cooling bath. Never insert a warm or a hot container into a cryogenic liquid alas spontaneous boiling and splashing of the cooling liquid will occur.
- Eyes must also be protected when working with cryogenics to avoid splashing. Cryogenic liquids boil rapidly when exposed to materials at room temperature.
- Dewars are the only vessels to be used for storing and transferring cryogenic liquids. Make sure they are properly clamped. Do not place Dewars on the floor. Dewars are vacuum sealed and can implode when damaged.
- In case a large volume of a cryogenic liquid should be dispensed from a low-pressure liquid nitrogen tank – use a wide-necked bottle and a cryogenic apron and a full-face shield to prevent splashes.
- Always work in well-ventilated areas or in the fume hood to avoid asphyxiation (nitrogen gas expands by a factor of 696). Asphyxiation can only occur when the oxygen content in the laboratory drops below 19.5%. Small and medium spills do not pose significant asphyxiation

hazards. In case of a large spill evacuate the premises. When possible close the valve of the liquid nitrogen container and open windows and doors to properly ventilate area. Only return when the oxygen content in the air has risen above 19.5%.

- Dry ice dissipates into the laboratory atmosphere, reaching a non-favorable concentration, therefore dry ice, which is not in use, should be stored outside the lab in a well-ventilated area.
 - Vacuum traps, which have been cooled down by liquid nitrogen, should never be exposed to the atmosphere, even for short time intervals, as the latter can cause liquid oxygen to condense in the trap.
 - In case liquid nitrogen is the coolant of the vacuum trap, make sure the pump is open and the Schlenk line is under active vacuum prior to commencing cooling. When using a Schlenk line – always make sure that the set-up does not leak and that it can hold a good static vacuum.
 - When freezing a solution in a Schlenk-flask or performing freeze-pump-thaw cycles, never leave the flask open to the inert atmosphere. always evacuate the flask to assure no gasses have been condensed into it prior to closing the flask.
 - If argon must be used as the inert atmosphere gas in a Schlenk line, always fill the vacuum trap with dry-ice/iso-propanol prior to cooling them with liquid nitrogen.
 - When working with a Dewar inside a vacuum trap, be alert for any hints of residual blue liquids (oxygen) inside the vacuum trap. If a blue liquid is observed, then liquid nitrogen / argon / oxygen have condensed into the trap, posing a highly dangerous situation. In this case return Dewar to its original position. Make sure the vacuum traps are cooled all the while using liquid nitrogen. Then, isolate Dewar from the (inert) atmosphere or from the leak to avoid additional condensation of gasses into the trap. Keep the vacuum pump ON. When working inside a fume hood - close the sash of the hood` when working outside the hood, put a blast screen around the Dewar containing the vacuum trap.
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- The use of **ionizing radiation** poses an external exposure risk, since ionizing radiation produces ions, which – in turn – could affect human tissues. Ionizing radiation includes the following radiation types: alpha (α), beta (β), gamma (γ), x and neutrons. Gamma and x radiations emit short-wavelength high-energized photons. Although ionizing radiation is invisible, its affects are cumulative.
- Be familiar with the properties of the radioisotope you work with. For example, there are special precautions for working with ^{35}S -methionine because of its volatility.
 - Rehearse unfamiliar radioisotope procedures before radioactive material is actually used.
 - Cover the work surface with protective and absorbent bench paper to trap droplets of contamination.



- The radioisotope working area should have a set of equipment that is only used for radioactive work. Depending on your protocol, this may include pipettors, a microcentrifuge, timers, mixers, a water bath, etc.
- Distance yourself as much as possible from the ionizing radiation source.
- Shorten the time interval you are working with ionizing radiation sources.
- Use proper PPE, especially when working with radioactive aerosols. For any work with an open radioactive source, wear:
 - ** Disposable gloves (latex or nitrile). Change your gloves frequently. Your radioactive solutions, especially when aliquoting from the stock vial, are likely to be highly concentrated. It is very easy to contaminate your gloves and spread contamination.
 - ** a full-length lab coat (worn closed with sleeves rolled down).
 - ** close-toed shoes. Never wear sandals or other open-toed shoes while working with radioactivity.
 - ** Goggles are required for any radioisotope procedure, specifically upon potential for the build-up of pressure that could release a spray of material.
 - ** Lab coat cuffs may hang down and drag across contaminated surfaces. To protect the skin of your wrists, consider wrapping tape around your lab coat sleeve or put a rubber band around the sleeve to keep the cuff from dragging or wear long gloves and tuck your lab coat into the gloves. Survey the skin of your wrists frequently as you work.
 - ** Keep an extra set of clothing and shoes in the lab in case your clothing becomes contaminated.
 - ** Avoid using petroleum-based hand creams when wearing gloves because petroleum-based hand creams may increase glove permeability.
- Survey your working area carefully before commencing radioactive work in case someone else left the work area contaminated or in case you missed contamination the last time you worked. In addition, survey frequently and extensively as you work. Don't assume that contamination will only be found on the bench top. Monitor your clothing, shoes and floor as well.
- Wear dosimetry radiation monitor badges when appropriate:
 - ** Wear ring badges under gloves to prevent the ring from getting contaminated. Make sure you don't discard the ring when you remove your gloves.
 - ** never leave chest badges exposed to an open radioactive source when not working with source. The badge should only count the exposure the employee was exposed to during radioactive work.
- Work in a fume hood during procedures using volatile materials such as I-125 or S-35 methionine/cysteine. Do not use biological safety cabinets (or laminar flow hoods) for work with volatile radioactive materials, since the air from the cabinet may be exhausted back to the room.

- During hybridization reactions, be sure to check the condition of the tubes to be sure the o-rings aren't dried out.
- Contaminated microcentrifuges must be cleaned following use to prevent contamination from spreading to other tubes and gloves. The following steps may help reduce the incidence of contamination:

** Wipe down the exterior of the tubes before placing them in the microfuge.

** Don't fill tubes more than 2/3 full.

** Use tubes with locking caps or with screwcaps.



- Do not eat or drink in any room labeled with a *Radioactive* sign on the door.
- Do not store food or beverages in refrigerators, freezers or cold rooms where radioactive sources are used or stored.
- Do not leave radioactive sources unsecured in an unattended lab, even for a short time, unless the lab is locked.
- If you discover that a radioactive source is missing and cannot be accounted for, notify the Safety & Radiation Unit ASAP, no later than the next business day.
- If there are no signs on a room in which radioactive sources are used or stored, contact the Safety & Radiation Unit to request labeling for the room.
- Label any container of radioactive source or piece of equipment in which a radioactive source is stored and any contaminated area or item with a designated tape.
- Label all contaminated items and containers.

Nonionizing radiation, such as UV radiation could result in temporary or constant damage, specifically to eyes and skin.



- When working in UV radiation-emitting environments, such as biological hoods or certain polymerization devices – use proper PPE: specific goggles, face mask, suitable gloves and thick protective clothing.
- **Laser radiation** is a concentrated beam of light at the visible or the non-visible spectrum. Radiation emitted of laser devices could result in serious damage to organs and tissues. There is a linear ratio between the extent of the biological damage imposed to the tissues and the intensity of the emitted laser radiation.

- Eyes must always be protected against direct contact with a laser beam. Specific goggles must be worn, The goggles must be specifically suited to the emitted laser radiation.
- Special protective side panels must be installed in laser devices to prevent radiation emission outside the path of the laser beam.

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- Energy spreaders must be installed in laser devices outside the effective range of the beam. The increasing use of [nanomaterials](#) in research labs warrants consideration as to their uncertain toxicity hazards. Nanomaterials include any materials or particles that have an external nanoscale dimension ($\approx 1 \text{ nm} - 100 \text{ nm}$). The most common types of nanomaterials are carbon-based. These include nanotubes, metals and metal oxides such as silver and zinc oxide and quantum dots made of compounds such as zinc selenide.

Nanomaterials can be categorized by the potential risk of exposure they pose to personnel based on the physical state of the materials and the conditions in which they are used. In general, the risk of exposure is lowest when nanomaterials are bound in a solid matrix with little potential to create airborne dust or when in a non-volatile liquid suspension.

- The risk of exposure increases when nanomaterials are used as fine powders or are suspended in volatile solvents or gases.
- The parent compound of the nanomaterial should also be taken into consideration when evaluating the potential hazards associated with exposure (a highly toxic compound such as cadmium should be anticipated to be toxic when used as a nanomaterial).