

SABANCI UNIVERSITY
NANOTECHNOLOGY RESEARCH
AND
APPLICATION CENTER



HEALTH AND SAFETY
HAND BOOK

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1 INTRODUCTION

This documentation provides the lab health and safety procedures and measures that the Sabanci University Nanotechnology Research and Application Center (SUNUM) apply for its laboratories..

Students, faculty lab associates and guest researchers and users should read and understand the information in this document with regard to laboratory safety and emergency procedures prior to the use of SUNUM facilities.

1.1 STRUCTURE OF THE HEALTH AND SAFETY PROGRAM AT SUNUM

The Health and Safety (H&S) Program of SUNUM is run by a committee which is assigned by SUNUM Director. The duties of the H&S Committee include the following:

- Providing technical guidance on matters of laboratory safety
- Developing and conducting training programs in laboratory safety
- Working with local officials on matters of codes and enforcement
- Assisting laboratory personnel with evaluating, preventing and controlling hazards
- Inspecting laboratories to assure compliance with safety and health guidelines and regulations, and to assist with remediation of safety issues
- Investigating accidents and recommending action to reduce the potential for recurrence
- Coordinating clean-up operations in the event of chemical spills or other contamination
- Overseeing the adoption and implementation of all health and safety policies

The Health & Safety Program at SUNUM should not be considered as confined only to this documentation, but also includes those ongoing activities coordinated by Sabanci University Rules and Regulation. However, the regulations and recommended actions in this document apply to the general and specific safety guidelines for the lab studies at SUNUM.

1.2 OUTLINE OF THE DOCUMENTATION

[Chapter 2](#) includes the general lab safety measures, and safety guidelines that are to be followed at practice, where the detailed subjects could be found at later chapters. [Chapter 3](#) includes information on emergency actions during fire, earthquake and hazardous material spills (chemical-biological). [Chapter 4](#) gives detailed information on how to work with chemicals on SUNUM Labs, including standard operation procedures, protective clothing, chemical procurement procedures and how to work with chemicals and experiment systems with specific properties. [Chapter 5](#) provides valuable information on biology labs and standard operation procedures according to the Biological safety levels. [Chapter 6](#) is the main guidebook for researchers that will work in SUNUM Clean Room – Micro nano Fabrication Labs. Basic rules and protocols, equipment's policies, facility hazards, chemical usage rules, and emergency actions at cleanroom are explained in detail in this chapter. [Chapter 7 and Chapter 8](#) suggest electrical and mechanical safety procedures and possible hazards whereas [Chapter 9](#) and [Chapter 10](#) provides information on Radiation/laser Safety and Superconducting magnet Safety related to researches followed at SUNUM. [Chapter 11](#) a newly introduced subject to Health and Safety at work but shows specific hazards possible during work with nanomaterials. [Chapter 12](#) proceeds with waste disposal procedures for chemical and biological materials.

2 LAB SAFETY

Working safely in a laboratory requires having the proper containment equipment and engineering controls, wearing appropriate personal protective equipment, using proper work practices, being aware of the safety rules for chemicals and equipment used, and following safety instructions and laboratory protocols are recommended.

The general safety information in this section is provided to assist researchers and supervisors in planning work and guiding those actually carrying out procedures. Because each laboratory situation is different, judgment is required in interpreting general concepts for individual settings. The Laboratory Safety Profile provides specific information for individual laboratories. If you have questions or concerns about implementing general safety concepts or specific safety procedures, consult SUNUM H&S.

Some laboratories contain more than one type of hazardous materials. For example, biochemistry laboratories may work with chemicals, biological agents, and radioactive materials. In such cases, the protective equipment and work practices to be used are those that provide protection against the most hazardous agent or meet the most stringent legal requirement.

Safety training and/or information should be provided by a faculty member, teaching assistant, lab supervisor or staff member at the beginning of a new assignment or when a new hazard is introduced into the workplace. Everyone should provide risk assessment form or MSDS file upon ordering a new chemical which has not been ordered previously, and does not have a MSDS file recorded.

2.1 SAFETY TRAINING

All new users in SUNUM will undergo a safety course and a practical introduction course (“hands on”) before gaining access to the center. Users must undergo the training program before access will be given to the Center.

The safety course provides some basic information about the SUNUM construction and its safety systems. Users also undergo essential risk training in SUNUM including guidelines for dealing with dangerous chemicals and work procedures that should be followed. Included during the training session is a guide about important safety aspects and a video on the working conditions in laboratories.

SUNUM training course consist of both general and specific training. The general “hands on” course runs for approximately 2 hours. This course deals with a number of practical details concerning general laboratory work. These include the correct procedure to dress in protective clothing, general behavior in the cleanroom, waste handling, review of safety equipment, use of chemical pumps, fire safety procedures, etc.

All users also receive specific training before working on Cleanroom and Biology Labs.

Cleanroom users must obtain SUNUM Safety Course before access to the Cleanroom is granted.

The course takes place with a minimum of 2-5 people.

The safety courses are usually held on September and February in accordance with the academic calendar. The course runs for 4-5 hours for both the theoretical and practical training. Course dates are announced in the [event calendar](#)¹. The safety course theoretical and practical training will be held separately due to the high number of participants.

After the safety course participants must take a multiple choice Safety Exam based on this manual and practical course they attended. Any users below 70% must take the safety course and exam again.

Card access to the SUNUM labs will be given after completion of the SUNUM User Information Form and SUNUM-Safety Rules Acceptance Form.

2.2 GENERAL SAFETY GUIDELINES

The following guidelines have been established to eliminate or minimize the risks in the laboratory. Standard operating procedures of equipment’s must be readily available for all laboratory users. These guidelines have also been provided to maintain a safe laboratory environment. The equipment should technically be operated due to their guidelines. The user manuals and operating procedures therefore should be kept on the bench or in the closet near to the equipment. The users have to be well trained for operational procedures and setting up proper instrumental parameters (e.g. electrical, magnetic or radioactive).

Responsibilities:

¹ Sunum.sabanciuniv.edu

Each individual in the laboratory is responsible for his/her own safety and for the safety of others affected by their work. This includes responsibility for:

1. Assessing the chemical and process hazards and planning and carrying out the experiment safely
2. The safe storage of the chemicals used
3. Emergency procedures to be taken in the event of an accident
4. The ultimate safe and appropriate disposal of all substances involved
5. Observing good personal hygiene practices

Overall responsibility for laboratory safety rests with researcher and/or laboratory supervisor and ultimately the Director of the Centre.

This section aims to refer basic safety procedures to be used. Refer to specific sections for proper and detailed procedures:

- Never perform any hazardous work alone in the laboratory. At least two people should be present.
- Always wear proper eye protection in chemical work, handling and storage areas. Contact lenses should normally not be worn. Fitted goggles are essential if, for therapeutic reason, contact lenses must be worn.
- Prepare and maintain a chemical inventory for the lab.
- Consult material safety data sheets (MSDS) before working with hazardous chemicals or infectious material. Replace MSDS that are more than 3 years old.
- Always know the hazards associated with the materials that are being utilized in the lab.
- Always wear appropriate protective clothing. Cover shorts, cut-offs or miniskirts with a suitable lab coat or apron.
- Confine long hair and loose clothing. Do not wear high-heeled shoes, open-toed shoes, sandals or shoes made of woven material.
- Always wash hands and arms with soap and water before leaving the work area. This applies even if you have been wearing gloves.
- Never perform unauthorized work, preparations or experiments.
- Never engage in horseplay, pranks or other acts of mischief in chemical or biological work areas.
- Never remove chemicals, biological agents, or radioactive materials from the facility without proper authorization.
- Be familiar with the location of emergency equipment - fire alarm, fire extinguisher, eye wash stations and safety showers. Know the appropriate emergency response procedures

- Use equipment and hazardous materials only for their intended purposes.
- Never mouth pipette chemicals when transferring solutions. Instead, you should always use a pipette bulb to transfer solutions.
- Always lubricate glass thermometers or thistle tubes before inserting them into a stopper.
- Always wrap towelings around them while inserting into the stopper.
- Use a hood whenever there is a possibility of poisonous or irritating fumes being emitted.
- Never leave an experiment unattended while it is being heated or is rapidly reacting.
- Keep equipment back from the edge of the lab bench to prevent spillage.
- Support all beakers and flasks with clamps. Do not use cracked or chipped glassware.
- Report accidents and dangerous incidents ("near-misses") promptly to your supervisor and SUNUM Facilities Management.
- Inform your supervisor and SUNUM Facilities Management if you realize that any equipment is broken, not working properly or not calibrated.

In General:

1. Do not use an unfamiliar experimental technique without having first gained further information, and if necessary, have it demonstrated to you. If in doubt, ask.
2. Read and observe all container label warnings and follow any precautions indicated.
3. Read the material safety data sheets for the chemicals involved.
4. Read and be familiar with the risk assessment for the experiment.
5. Substitution should always be considered- always use the least toxic, least flammable chemical compatible with the procedure.
6. The scale of the any experimental procedure should be as small as is reasonably practicable. Scaling up should not be undertaken without re-assessing the risks.
7. Work that requires personal control should never be left unattended.
8. Work that is to continue unattended overnight must have a label including the name of researcher, contact number and hazard warning in case of an incident.

2.3 WORKING ALONE POLICY

Use of the SUNUM labs requires that two users be in the Lab area at all times. During normal operation hours this requirement is generally satisfied by the presence of the staff. Outside normal business hours it is necessary to ensure that you are not working alone in the laboratory. It is the user's responsibility to coordinate with another user to ensure that two people are in the laboratory.

Working alone is an unsafe practice at any time, as help is not readily available. However, if the nature of your work makes it unavoidable, take precautions to ensure that others are aware of your location and have someone check in with you from time to time, either in person or by telephone. Before conducting any work alone in a laboratory go through this checklist to determine if it is appropriate to proceed:

- Is your supervisor aware of your plans?
- Are there any hazardous chemicals involved?
- Lone working must be risk-assessed and agreed with your supervisor on a case by case basis.

Examples:

- High temperature
- High vacuum
- Extremely flammable or explosive materials (low flash point)
- Poisonous materials, carcinogens, mutagenes and substances toxic to reproduction.
- Scaling up i.e., higher quantities

2.4 PREPARING FOR LABORATORY WORK

Before starting to work in a laboratory, familiarize yourself with the following:

1. Have you reviewed your procedure with your supervisor?
2. Do you have a written operating procedure?
3. Are your apparatus and equipment in good working condition?
4. Are you trained to carry out the work?
5. Do you have a check-in/check-out procedure?
6. Do you have an emergency contingency plan?
7. Do you have access to a telephone (rather than a cell) in case of an emergency?
8. Does your door have a viewing window or other means of indicating someone is inside?
9. Are you aware of the emergency evacuations procedure?

10. Do you have access to a first aid kit?

11. Do you have access to a spill kit?

2.5 DURING LABORATORY WORK

- Restrict laboratory access to authorized persons only. Children are not permitted in labs.
- Smoking; eating; drinking; storing food, beverages or tobacco; applying cosmetics or lip balm and handling contact lenses are not permitted in laboratories.

Wear lab coats (knee length) and safety glasses in laboratories employing chemicals, biohazards or radioisotopes. Open shoes, such as sandals, should never be worn in the lab.

- Tie back or otherwise restrain long hair when working with chemicals, biohazards, radioisotopes, or moving machinery.
- Keep work places clean and free of unwanted chemicals, biological specimens, radios, and idle equipment. Avoid leaving reagent bottles, empty or full, on the floor.
- Work only with materials once you know their flammability, reactivity, toxicity, safe handling and storage and emergency procedures.
- Never pipette by mouth; use mechanical transfer devices.
- Walk; do not run, in the lab.
- Keep exits and passageways clear at all times.
- Ensure that access to emergency equipment (eyewashes, safety showers and fire extinguishers) is not blocked.
- Wash your hands thoroughly before leaving the laboratory.
- Conduct procedures involving the release of volatile toxic or flammable materials in a chemical fume hood
- Perform procedures that liberate infectious bio-aerosols in a biological safety cabinet.
- Handle all human blood and body fluids as if potentially infectious.
- Zero dishes rule: Wash and place all the glassware used in autoclave before leaving,
- Make sure all chemicals used are placed in provided cabinets before leaving
- Switch off the equipment after use, cover with protective coats/caps if present.
- Please take into account that some equipment should NEVER be completely switched off (e.g. Electron Microscopes), Turn off the main/service PC and user interface only before leaving!!!
- Leave the experimental areas clean and free from personal documents and samples for next users

- Separately dispose of plastics and paper towels in the bins provided.

2.6 CLEANING UP BEFORE LEAVING

Perform a safety check at the end of each experiment and before leaving the lab. Make sure to [3]:

- Turn off gas, water, electricity, vacuum and compression lines and heating apparatus if opened before starting the experimental procedure.
- Return unused materials, equipment and apparatus to their proper storage locations.
- Label, package and dispose of all waste material properly (Refer to Section 12, Waste Disposal Procedures")
- Remove defective or damaged equipment immediately, and arrange to have it repaired or replaced
- Decontaminate any equipment or work areas that may have been in contact with hazardous materials.
- Leave behind protective clothing (lab coats, gloves, etc.) when leaving the laboratory.
- Close the laboratory door if you are the last one to leave.

2.7 EVALUATING LABORATORY HAZARDS, AN ONGOING PROCESS

There are many categories of hazards that might be encountered in a laboratory setting, and situations can change frequently. Even after you have identified and controlled all possible risks, unexpected risks can still occur. Periodically check that the Laboratory Information Card (LIC) and other hazard warnings are up-to-date and notify SUNUM Management whenever changes to the LIC are required.

Carry out weekly inspections for:

- Fire extinguishers
- Emergency wash devices such as eyewashes and drench hoses (run these for several minutes and update inspection tags
- First aid kit contents
- Fume hood and other ventilation equipment
- Tubing for circulating water, vacuum, gases
- Chemical storage compartments

Also, ensure that fire extinguishers and emergency showers are inspected, tested and tagged annually. Among potential laboratory hazards, be alert for the following:

Chemical products

- Flammable
- Toxic
- Oxidizing
- Reactive
- Corrosive

Infectious agents

- Viruses
- Bacteria
- Parasites
- Rickettsiae
- Fungi

Physical or mechanical hazards

- Ionizing and non-ionizing radiation
- Electrical
- Laser radiation
- Poor equipment design or work organization (ergonomic hazards)
- Tripping hazards
- Excessive noise
- Heat or cold

Psychosocial conditions that can cause psychological stress

2.8 SABANCI UNIVERSITY NANOTECHNOLOGY RESEARCH AND APPLICATION CENTER LABORATORIES

Table 1

Micro-Nano Fabrication (Clean Room)	
G131	Photolithography Room
G133	Thin Film Etching Room
G 135	Thermal Processing Room
G137	Focused Ion Beam Room
G138	Gowning Room
G139	Thin Film Deposition Room
G141	Wet Processing Room
G143	E-Beam Lithography Operator Room
G144	E-Beam Lithography Room
G145	Microsystems Packaging Room
Electron Microscopy and Spectroscopy Laboratory	
G146	TEM 1 Room
G146A	TEM Utility Area
G147	TEM 2 Room
G148A	SEM Room
G149	Sample Preparation Lab
General Wet-Labs	
G150	Nano Magnetism Laboratory
G150A	UHV-LFM Laboratory
G150B	UHV-AFM Laboratory
G152	Nano Electronics Laboratory
G153	LT-STM Laboratory
G155	Material Characterization Laboratory
G156	Crystal Growth Laboratory
G157	3D Systems Design and Fabrication Laboratory
G160	Energy and Surface Chemistry Laboratory
G161	Confocal Microscopy Laboratory
G162	Tissue Culture Laboratory
G164	Microsytems Test Laboratory

G165	Anechoic Chamber
G166	Microfluidics and Microthermal Systems Laboratory
G168	Tissue and Regenerative Engineering Laboratory
Molecular Biology Laboratories	
G159	Molecular Biology Laboratory
G154	DNA Sequencer Room
G158	PCR Preparation Room
G158A	Library Preparation Room
G159A	Freezers
G159B	Cold Room
G159C	Mass Spectroscopy Room

Table 1 SUNUM laboratories

3 EMERGENCY ACTION PLAN

3.1 SABANCI UNIVERSITY EMERGENCY NOTIFICATION

7555-5555; (0-216-568-7555 ; 0-850-205-7555) (Do not dial 9988)

Do not waste time calling other people!

Emergency Phone Numbers which can be used
Monday through Friday 8:40 AM to 5:00 PM:

SUNUM-Chemical Spills-**7474 (0-216-568-7474)**

SUNUM-Biohazard Spills-**7474 (0-216-568-7474)**

SUNUM-Security-**7100**

Procedure for an Emergency:

- 1) Evacuate the laboratory.
- 2) Close all doors.
- 3) In case of fire or explosion, pull nearest fire alarm.
- 4) Call **7555-5555; (0-216-568-7555 ; 0-850-205-7555)** or other emergency phone number from a safe place.
- 5) Go directly to the assembly point.

3.2 USEFULL PHONE NUMBERS NEEDED IN EMERGENCY STUATIONS

Yangın İhbar/Fire Emergency Line	110
Tuzla İtfaiye/Tuzla Fire Department	3955004
Aydınlı İtfaiye/Aydınlı Fire Department	39332 92
Polis İmdat/Police Emergency Line	155
Hızır Acil Servis/Helath Emergecny Line	112
Ulusal Zehir Danışma Merkezi/Natianal Hazard Communication Center	114
Med Line	0212 249 62 60
İl Afet Koordinasyon Merkezi (AKOM)	0 212 321 17 39
Tuzla Sivil Savunma Md.	395 25 41
Tuzla Emniyet Md	395 79 98, 395 83 21
Jandarma İmdat	156
Tuzla İlçe Jandarma Komutanlığı	394 25 21
Akfirat Jandarma Karakolu	677 14 40
Tuzla Kaymakamlığı	395 78 23
Tuzla Belediyesi	392 58 22, 392 23 70, 392 61 35
Tuzla İSKİ	395 00 41

3.3 FIRE RESPONSE

A fire within a laboratory and/or classroom can grow in both size and severity, rapidly and without warning. Extreme caution must be used particularly, if the decision is made to attempt to extinguish a fire, of any size.

Some basic information, regardless of the size of the fire;

- Activate the nearest building alarm (fire pull station-Figure 1). If not available or operational, verbally notify people in the building by **calling (FIRE AT ... !!!)**



Figure 1 Fire Pull down station

- Identify someone to **DIAL 7555-5555; (0-216-568-7555 ; 0-850-205-7555)** to report the fire, if you are alone in the area, make the call yourself. Get emergency services started your way, even if it is just a “Small” fire; it could increase in size rapidly.
- If you were involved with the fire, identify yourself to the response personnel, you may have important information regarding the substance involved, personnel in the area, location or extent of the fire, etc.,
- If you must evacuate the area, close doors behind you and do not re-enter the building until told by the Officials.
- Do not “Swipe” or attempt to “Brush” at a small fire with your hand, rag, towel, or similar object. You may spread the fire further or spill and ignite other flammable liquids.
- Do not attempt to extinguish a fire if:
 - a) You feel it is unsafe to do so.
 - b) You notice odd colored smoke or experience physical symptoms of exposure such as eye or skin irritation, difficulty breathing, coughing, dizziness or nausea. (Always, obtain

medical attention immediately when experiencing any of these symptoms. **DIAL 7666-6666; (0-216-568-7666 ; 0-850-205-7666))**

- c) You do not have the proper equipment or training.
- Have the used extinguishers recharged immediately.
- When you hear and/or see a fire alarm (Figure 2) activate within your building, **EVACUATE THE BUILDING IMMEDIATELY.**



Figure 2 Fire Alarms

If the fire alarms are ringing in your building:

- You must evacuate the building and stay out until notified to return.
- Do not use the lifts.
- Move upwind from the building and stay clear of streets, driveways, sidewalks and other access ways to the building.
- If you are a supervisor, try to account for your employees, keep them together and report any missing persons to the emergency personnel at the scene.

3.3.1 Small Fire (trash can size)

- 1) Notify people in the immediate area that there is a fire.
- 2) Identify someone to **DIAL 7555-5555; (0-216-568-7555 ; 0-850-205-7555)** to report a fire, if you are alone in the area, make the call yourself.
- 3) Some small fires, within contained vessels, can be easily smothered using a beaker, watch glass, or similar glassware, if it is safe to do so.

- 4) A properly operated fire extinguisher can be used on a small fire if necessary. Figure 3
- 5) Fire extinguishers can be found in fire lockers located at every corridor and also at dedicated spaces at necessary points within the vicinity of risky points.
- 6) Remember the P.A.S.S coding to contain the fire: Pull-Aim-Squeeze-Sweep



When To Fight The Fire...

Fight the fire only if all of the following are true:

- Everyone has left or is leaving the building.
- The fire department is being called.
- The fire is small and confined to the immediate area where it started (wastebasket, cushion, small appliance, etc.).
- You can fight the fire with your back to a safe escape route.
- Your extinguisher is rated for the type of fire you are fighting and is in good working order.
- You are trained to use the extinguisher and know you can operate it effectively.

If you have the slightest doubt about whether you should fight the fire — **DON'T!** Instead, get out and close the door behind you.

PROTECT YOURSELF AT ALL TIMES!

Stay low. Avoid breathing the heated smoke and fumes or the extinguishing agent.

If the fire starts to spread or threatens your escape route, get out immediately!

Remember:

If you are called on to use an extinguisher, just think of the word "**P.A.S.S.**"

PULL

the safety pin at the top of the extinguisher.

AIM

the nozzle or hose at the base of the flames. Stay between six and eight feet away from the flames.

SQUEEZE

or press the handle.

SWEEP

from side to side at the base of the fire until it goes out.

By following these procedures, a fire can be extinguished in the quickest and safest manner possible.

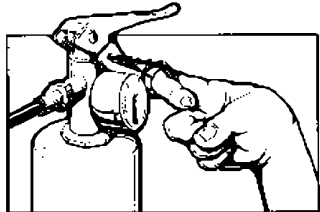
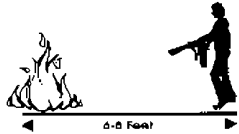
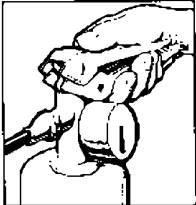






Figure 3 Fire Extinguishers and PASS coding

3.3.2 Large Fire (requiring more than 1 fire extinguisher)

- 1) Notify people in the immediate area that there is a fire.
- 2) Make sure all people are evacuated from the fire area.
- 3) If possible, notify your supervisor and/or floor warden.
- 4) Confine the fire. Close all doors and windows. Close the fume hood sash if the fire is inside the fume hood.
- 5) Activate the nearest fire alarm.
- 6) Locate the nearest campus telephone away from the fire area and **DIAL 7555-5555; (0-216-568-7555 ; 0-850-205-7555)** . (Cell phones will mis-connect you, or it will connect you with off-campus dispatch, and both of this causing delay to responding resources.)
- 7) When leaving the room where there is a fire, do not enter into another room where smoke or fire is already present.
 - a) Test the door by using the back of your hand before entering any room.
 - b) If the door is hot or warm, do not open the door.
 - c) If smoke is present, crawl on your hands and knees to keep your head low and out of the smoke.
 - d) If your exit is blocked by smoke or fire, hang a piece of cloth out a window, nearest the street (if possible). Make sure all doors and windows are closed into the room.
- 8) Evacuate the area by USING THE STAIRWELLS. Never use the elevators and follow the evacuation plan for your laboratory.
- 9) NEVER re-enter the building until told by Officials.

3.3.3 Clothing on Fire

- 1) If your clothes catch on fire, remember to STOP-DROP-&-ROLL-ROLL-ROLL. This action will smother the fire. Protect your face with your hands.
- 2) Safety showers or fire extinguishers are useful only when immediately at hand. Do not use a fire blanket.
- 3) Always obtain medical attention when burned. **DIAL 7555-5555; (0-216-568-7555 ; 0-850-205-7555)** .

Note: Wrapping a fire blanket around a victim, whose clothing is burning, is not recommended. It may smother the fire on the body of the victim, but it will cause the fire to move to the victim's head.

3.4 CHEMICAL SPILLS

Try to anticipate the types of chemical spills that can occur in your laboratory and obtain the necessary equipment (spill kits and personal protective equipment) to respond to a minor spill. Learn how to safely clean up minor spills of the chemicals you use regularly. An MSDS contains special spill clean-up information and should also be consulted. ***Chemical spills should only be cleaned up by trained, knowledgeable and experienced personnel.***

If the spill is too large for you to handle, requires you to put on respiratory protection, is a threat to personnel, students or the public, or involves a highly toxic or reactive chemical, call for assistance immediately, or **PUSH EMERGENCY BUTTON** next to the lab door. It will activate the emergency signal and siren. Figure 4 Figure 5



Figure 4 Emergency Button



Figure 5 Signal and Siren

SUNUM Facility Management: (8:40 am to 5:00 pm M-F)

SUNUM Lab Supervisors: (7474 (0-216-568-7474))

University Emergency Phones: (all other times)

University Security: (7555-5555; (0-216-568-7555 ; 0-850-205-7555))

SUNUM Security: (7100)

SUNUM Facility Management is equipped to handle most spills that can occur at the University. If there is the slightest doubt regarding how to proceed, call for assistance!

The following compounds are very hazardous. **You should not clean them up yourself:**

- | | | |
|--------------------|----------------------|-----------------------|
| - Aromatic amines | - Hydrazine- Bromine | - Organic Halides |
| - Carbon disulfide | - Nitriles | - Ethers and other 1A |
| - Cyanides | - Nitro compounds | flammable solvents |

3.4.1 Cleaning Up Chemical Spill

If you are cleaning up a small spill yourself, make sure that you are aware of the hazards associated with the materials spilled, have adequate ventilation (open windows, chemical fume hood on) and proper personal protective equipment (minimum - gloves, goggles, and lab coat). Consider all residual chemical and cleanup materials (adsorbent, gloves, etc.) as hazardous waste. Place these materials in sealed containers (plastic bags), label, and store in a chemical fume hood. Contact Lab Supervisors for disposal instructions and pickup.

3.4.2 Minor Chemical Spill

- Alert people in immediate area of spill.
- Increase ventilation in area of spill (open windows, turn on hoods).
- Wear protective equipment, including safety goggles, gloves, long-sleeve lab coat and closed toe shoes.
- Avoid breathing vapors from spill.
- Use appropriate kit to neutralize and absorb inorganic acids and bases. Collect residue, place in container, and dispose as hazardous chemical waste. Call Lab Supervisors for disposal information, if necessary.
- For other chemicals, use appropriate kit or absorb spill with vermiculite, dry sand, diatomaceous earth, spill pads, or paper towels. Collect residue, place in container, and dispose as chemical waste.
- Clean spill area with water.

3.4.3 Major Chemical Spill

- Attend to injured or contaminated persons and remove them from exposure.
- Push the **Emergency Button** next to lab door.
- Alert people in the laboratory to evacuate.
- If spilled material is flammable, turn off ignition and heat sources. Place spill cleanup material over spill to keep substance from volatilizing. An MSDS contains special spill clean-up information and should also be consulted.
- **Call** SUNUM Facility Management **7474 (0-216-568-7474)** or **7555-5555; (0-216-568-7555 ; 0-850-205-7555)** any time.
- Close doors to affected area.
- Have a person with knowledge of the incident and laboratory available to answer questions from responding emergency personnel.

3.5 BIOLOGICAL MATERIAL SPILLS

The consequences of any spill of biological material can be minimized by performing all work on plastic-backed absorbent liner to absorb spills.²

A well designed spill kit is highly recommended. It can save injury, time, and resources. The following items would be excellent choices for a Biohazard Spill Kit:

- An appropriate chemical decontaminant -- in most cases a 10% household bleach solution is a good choice, but keep in mind that bleach will corrode stainless steel if left in contact with it for 30 minutes or more. For human blood and body fluids, iodophors or 70% alcohol is appropriate;
- Materials to absorb liquids after decontamination -- this could include paper towels, absorbent lab pads, or special materials designed to absorb large volumes of liquid. Keep in mind the volumes of liquid typically used in the laboratory area when selecting an absorbent;
- Appropriate personal protective equipment to wear during clean-up -- gloves and a long-sleeved laboratory coat or gowns is always necessary. Facial protection equipment should be considered for large spills as well as protection against splash and splatter of the chemical decontaminant. Additional personal protective equipment is necessary when working with Class 3 agents.
- A mechanical means for handling broken glass -- this could include tongs, forceps, small disposable scoops and sponges, auto-clavable dust pans, or any other method that prevents direct contact with the broken glass. Broken glass represents a high cutting danger and should not be touched directly, especially if it is contaminated with a biohazardous agent;
- Biohazard bags, auto-clavable bags, sharps containers, and/or other containers to place the material in for further treatment and disposal³

² <http://web.princeton.edu/sites/ehs/emergency/biospill.htm>

³ <http://www.pprc.org/mirt/meetings/spills.pdf>

3.5.1 Bio Safety Level 1 Organism Spill

Risk Group 1 infectious agents are biological agents that are unlikely to cause disease in healthy workers or animals (low individual and community risk). ⁴

- Wear disposable gloves.
- Soak paper towels in disinfectant and place over the spill.
- Place towels in a plastic bag for disposal.
- Clean up spill area with fresh towels soaked in disinfectant.

3.5.2 Bio Safety Level 2 Organism Spill (Moderate Risk Agents)

Risk Group 2 infectious agents are pathogens that can cause human or animal disease but, under normal circumstances, are unlikely to be a serious hazard to laboratory workers, the community, livestock, or the environment (moderate individual risk, limited community risk). Laboratory exposures rarely cause infection leading to serious disease; effective treatment and preventive measures are available and the risk of spread is limited. ⁵

- Alert people in the immediate area of the spill.
- Put-on protective equipment. This may include a laboratory coat with long sleeves, back-fastening gown or jumpsuit, disposable gloves, disposable shoe covers, safety goggles, mask or full-face shield.
- Cover the spill with paper towels or other absorbent materials.
- Carefully pour a freshly prepared 1 to 10 dilution of household bleach around the edges of the spill and then into the spill. Avoid splashing.
- Allow a 20-minute contact period.
- After the spill has been absorbed, clean up the spill area with fresh towels soaked in disinfectant.
- Place towels in a plastic bag and decontaminate in an autoclave.

3.5.3 Spills on the body

⁴ http://www.ccac.ca/en/CCAC_Programs/ETCC/Module04/15.html

⁵ http://www.ccac.ca/en/CCAC_Programs/ETCC/Module04/15.html

- Remove contaminated clothing.
- Vigorously wash exposed area with soap and water for one minute.
- Seek medical treatment (if necessary).
- Report the incident to the laboratory supervisor.

3.5.4 Spills within a biological safety cabinet

- 1) Leave the ventilation on
- 2) All items within the cabinet should be disinfected (Walls and surfaces wiped down, equipment wiped down and/or autoclaved).
- 3) Cover the spill area with paper towels or absorbent material
- 4) Soak the spill area with an appropriate disinfectant (i.e. 10% bleach). Pour the disinfectant from the outside surface of the absorbent material towards the inside.
- 5) Leave on for 20 to 30 minutes
- 6) Pickup with absorbent material
- 7) All waste should be autoclaved
- 8) Ventilation should run 10-15 minutes
- 9) If the spill overflows onto the interior of the BSC contact the technical service as a more extensive decontamination may be required.⁶

3.5.5 Spills inside a centrifuge

- 1) Leave lid closed and allow aerosols to settle for at least 1 hour (ensure centrifuge is off)
- 2) Notify others in the lab not to use the centrifuge (include signage) and inform the lab supervisor
- 3) If possible move the centrifuge or at least the rotors and buckets to a BSC
- 4) Disinfect the centrifuge or rotors and buckets in an appropriate disinfectant, allow at least 20 to 30 minutes of contact time.
- 5) Carefully retrieve any broken glass from inside the centrifuge using forceps and place in a sharps container.
- 6) Drain the disinfectant.
- 7) Thoroughly wipe down the inside of centrifuge and all parts including the lid with paper towels soaked in disinfectant
- 8) Rinse both the rotors and the inside of the centrifuge with water if bleach was used.

⁶ <http://www.uottawa.ca/services/ehss/biospill.htm>

- 9) All waste should be autoclaved⁷

3.5.6 Spills outside of a biological cabinet, in a laboratory

Biological spills outside biological safety cabinets will generate aerosols that can be dispersed in the air throughout the laboratory. These spills are very serious if they involve microorganisms that require Biosafety Level (BSL) 3 containment, since most of these agents have the potential for transmitting disease by infectious aerosols.⁸

- Notify others.
- If an aerosol is generated (or the risk exists), hold your breath and quickly leave the lab. Close the door and post a warning sign. Evacuate the area for at least 30 minutes to allow aerosols to settle.
- Remove any contaminated clothing. For more hazardous substances place the contaminated clothing in an appropriate bag for autoclaving.
- Thoroughly wash exposed skin with soap and water.
- Assemble cleaning supplies and PPE
- Cover the spill area with paper towels or absorbent material
- Using an appropriate concentrated disinfectant cover the spill area. Pour disinfectant from the outside, towards the inside of the spill.
- Pick up any broken glass with forceps and place in a sharps container.
- Cover with absorbent material. For more hazardous substances, allow the disinfectant to act for 20 minutes.
- All adjacent areas should also be disinfected or wiped down.
- All waste should be autoclaved.⁹

3.5.7

3.5.8 Spill Involving Human Blood and Body Fluids

- 1) Alert people in immediate area of spill.
- 2) Any Students, faculty and lab associates exposed to human blood and body fluids must cleanse the affected areas as soon as possible:
- 3) Skin contact/cuts/puncture wounds: wash with soap and water, then pour 3% hydrogen peroxide over the cut/lesion or wash with either chlorhexidine or iodophor.
- 4) Eyes: flush with water

⁷ <http://www.uottawa.ca/services/ehss/biospill.htm>

⁸ <http://risk.arizona.edu/emergencyprocedures/biologicalspill.shtml>

⁹ <http://www.uottawa.ca/services/ehss/biospill.htm>

- 5) Mouth: rinse well with 3% hydrogen peroxide and then water
- 6) Inform the lab supervisor of exposure.
- 7) Properly trained Students, faculty and lab associates must proceed with the cleanup and decontamination of the spill area.
- 8) Put on protective equipment (full face shield or mask and safety glasses/goggles, latex gloves, lab coat).
- 9) Pick out any sharps using tongs or other mechanical means and cover spill absorbent material such as paper towels.
- 10) Carefully pour a freshly prepared 1 in 10 dilution of household bleach around the edges of the spill and then into the spill. Avoid splashing.
- 11) Allow a 20 minute contact period.
- 12) Use paper towels to wipe up the spill, working from the edges into the center.
- 13) Clean spill area with fresh paper towels soaked in bleach solution.
- 14) Place towels in a red bag for disposal.
- 15) Remove protective equipment and wash hands thoroughly.¹⁰

3.5.9 Spill Involving a Microorganism Requiring BSL 1 or BSL 2 Containment

- Alert people in immediate area of spill.
- Put on proper personal protective equipment.
- Cover spill with paper towels or absorbent pads.
- Carefully pour a freshly prepared 10% (vol./vol. w/water) dilution of household bleach around the edges of the spill and then into the spill. Avoid splashing.
- Allow a 20-minute contact period.
- Use paper towels to wipe up the spill, working from the edges into the center.
- Clean spill area with fresh towels soaked in disinfectant.
- Place towels in a red plastic bag for disposal in the biohazardous waste.

3.5.10 Spills outside the Laboratory (During Transport)

If a biohazardous agent is spilled during transport outside the laboratory, the main difference from the [first procedure](#) is to initiate the cleanup immediately. Otherwise, use those procedures.

¹⁰ <http://www.safety.rochester.edu/ih/emergenc.html>

Because it would already be too late to prevent aerosolization in this case, it is better to place extra emphasis on prevention of spills during transport:

- 1) Develop a procedure for the removal of biohazardous materials for incubation, refrigeration, or for any other reason from the laboratory, and enforce adherence to it;
- 2) Place all such materials in an unbreakable container that would prevent the escape of liquid or aerosol if it were dropped. One-gallon or half-gallon paint pails are good examples of acceptable containers;
- 3) Label the container with the biohazard symbol to ensure no mistake is made as to the contents.¹¹
- 4) Viable organisms should only leave the laboratory in a well-sealed primary (inner) and secondary (outer) container with a closable top. A test-tube rack inside a tray is not acceptable.
- 5) The exterior of the secondary container should be wiped down with disinfectant prior to leaving the laboratory so that it can be transported without wearing gloves.
- 6) Carry paper towels and if a spill occurs use the towels to cover the spill but do not attempt a clean-up without appropriate disinfectant and personal protective equipment.
- 7) Notify people in the immediate area and collect clean-up material and proceed with clean-up¹²

3.5.11 Exposures and Injuries

The procedures, activities, personnel attitudes, and equipment that create conditions favorable for occupational laboratory infections are similar to those that lead to the occurrence of industrial type accidents.

The extra ingredient is the presence of biohazardous agents capable of causing human infections. Laboratory events that might create hazards, exposures, or accidents requiring reporting could be classified in two categories:

- Events occurring during work with biohazardous materials or in a biohazardous area that could result in physical injury, cuts, burns, abrasions, or fractures.

¹¹ <http://www.ehs.washington.edu/rbsbiosafe/spillsbio.shtm#third>

¹² <http://ehs.columbia.edu/biospill.html>

- Events occurring during the handling of biohazardous agents, infected specimens, or animals that could allow release of the agent to the environment or its undesired transfer to Students, faculty and lab associates, animals or cultures.

In the first category the injury site could be contaminated with the biohazardous agent in use. In the second category illness or unwanted cross contamination could occur without physical injury. Mechanisms of infection typical of the second category are ingestion of contaminated fluids, exposure to aerosols, and penetration of agents through the unbroken skin.



Therefore, for the purpose of controlling biohazards, all accidents, known exposures, and potential hazards must be identified and reported.¹³

3.5.11.1 Procedure Following Exposure To Bloodborne Pathogens

A bloodborne pathogen exposure incident occurs when potentially infectious material comes into contact with the eyes, mouth, other mucous membrane, or damaged skin, or penetrates the skin (parenteral or under the skin) during the performance of an Students, faculty and lab associates's duties.

A. In the Event of Exposure to Bloodborne Pathogens:

1. Immediately wash the exposed area with soap and water. For eye and mucous membrane exposure, rinse with water for 10 to 15 minutes.
2. Notify the supervisor immediately after the bloodborne pathogen exposure incident and provide detailed information about the incident.
3. Immediately following washing, Students, faculty and lab associatess should contact the following medical providers for post-bloodborne pathogens exposure evaluation and/or medical treatment

Biological Aerosol Exposures

- Hold breath and immediately leave the room.
- Remove PPE carefully: turn exposed areas inward.

¹³ http://www.lbl.gov/ehs/biosafety/Biosafety_Training/html/bio_incident_resp_.shtml

- Wash hands well with soap and water.
- Post spill sign, lab should be evacuated for at least 30 minutes. Principal Investigator must clear lab for re-entry. ¹⁴

Needle sticks and Puncture Wounds (with infectious agents)

- Treat affected area.
- Wash well with disinfectant or antiseptic soap and water for 15 minutes (iodine is preferred).
- Squeeze around affected area to encourage bleeding.

Splash to Face

- Flush infected area in eye wash for 15 minutes.
- NOTE: If the accident generates an aerosol (i.e. spill outside the biosafety cabinet) leave the laboratory promptly and follow the response procedures at a safer location. Identify a backup location prior to initiation of work. ¹⁵

¹⁴ <http://www.yale.edu/ehs/emergency2.htm>

¹⁵ <http://www.yale.edu/ehs/emergency2a.htm>

3.6 HAZARDOUS/TOXIC/FLAMMABLE GAS LEAK

In case of accidental release of a poisonous or hazardous gas, such as a leaking cylinder, turn off all ignition sources (if time permits), evacuate the area immediately and close the door.

- 1) Immediately implement SUNUM [emergency spill response plan](#).
- 2) In the event personnel have become contaminated immediately implement personal decontamination procedures.
- 3) If inhaled, remove to fresh air and **Call 7666-6666; (0-216-568-7666 ; 0-850-205-7666)** for immediate medical attention.
- 4) The MSDS sheet for the poisonous gas should be brought to the hospital to aid in treatment.

3.7 EARTHQUAKE RESPONSE

If you are indoors when shaking starts:

1. “DROP, COVER AND HOLD ON.” If you are not near a strong table or desk, drop to the floor against an interior wall and cover your head and neck with your arms.
2. Avoid windows, hanging objects, mirrors, tall furniture (filing cabinets and bookshelves), large appliances and cabinets filled with heavy objects.
3. Do not try to run out of your building during strong shaking—you can be killed or injured by falling debris (glass, roof tiles, concrete, etc.).
4. If you are on campus, it is safer to remain inside a building after an earthquake unless there is a fire or gas leak. There are open spaces in parking areas and University Center far enough from glass or other falling debris to be considered safe refuge sites. Glass from high-rise buildings does not always fall straight down; it can catch a wind current and travel great distances.
5. Do not use elevators.
6. If you use a wheelchair, lock the wheels and cover your head.

If you are outdoors when shaking starts:

- Move to a clear area if you can safely walk. There are no overhead power lines on the campus, but you should avoid buildings and trees.

- If you're driving, pull to the side of the road and stop. Avoid stopping under overhead hazards or near buildings.

Once the earthquake shaking stops:

1. Be prepared for aftershocks—they may be frequent and could exceed the first quake.
2. Check the people around you for injuries; provide first aid. Do not move seriously injured persons unless they are in immediate danger of a gas leak, hazardous material spill, fire or falling debris.
3. Check around you for dangerous conditions such as fires, downed power lines and structure damage.
4. If you have fire extinguishers and are trained to use them, put out small fires immediately.
5. Check your phones to be sure they have not shaken off the hook and are tying up a line.
6. Inspect your work areas for damage.

If you are trapped in debris:

Move as little as possible so that you don't kick up dust. Cover your nose and mouth with a handkerchief or clothing.

Tap on a pipe or wall so that rescuers can hear where you are. Use a whistle if one is available.

Shout only as a last resort.

4 CHEMICAL HYGIENE PLAN

4.1 INTRODUCTION

The Chemical Hygiene Plan applies to all laboratories at SUNUM.

The safe storage, use and disposal of chemicals in the laboratory require policies for the protection of students, faculty, associates and the environment. The purpose of this Chemical Hygiene Plan is to provide with basic safety information regarding the use of chemicals. This Chemical Hygiene Plan forms the foundation of the safe use of chemicals in the laboratory.

The standard operating procedures (laboratory practices and engineering controls) recommended in this manual identify the safeguards that should be taken when working with hazardous chemicals. These safeguards will protect laboratory workers from unsafe conditions in the vast majority of situations.

This manual is not intended as an encyclopedia of chemicals and their hazards; it will not contain listings of hundreds of chemicals that Students, faculty and lab associatess may encounter while working in research and development. Although numerous chemicals may be mentioned for the most part they will serve as illustrations for broad categories of hazards, except in the case of chemical incompatibility charts or listings.

4.1.1 Hazardous Chemical Definition

The OSHA Laboratory Health Standard defines a hazardous chemical as any element, chemical compound, or mixture of elements and/or compounds which is a physical hazard or a health hazard. The standard applies to all hazardous chemicals regardless of the quantity.

A chemical is a physical hazard if there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, organic peroxide, an oxidizer or is pyrophoric, flammable, or reactive.

A chemical is a health hazard if there is statistically significant evidence, based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed students, faculty and lab associates. Classes of health hazards include:

- Carcinogens
- Reproductive toxins
- Irritants
- Corrosives

- Sensitizers
- Hepatotoxins
- Agents that act on the hematopoietic system
- Agents that damage the lungs, skin, eyes, or mucus membranes
- Neurotoxins
- Nephrotoxins
- Asphixiants

In most cases, the chemical container's original label will indicate if the chemical is hazardous. Look for key words like caution, hazardous, toxic, dangerous, corrosive, irritant, carcinogen, etc.

4.1.2 HAZARD IDENTIFICATION

Some laboratories will synthesize or develop new chemical substances during the course of their research. If the composition of the substance is known and will be used exclusively in the laboratory, the researcher must label the substance and determine, to the best of his/her ability, the hazardous properties (e.g. corrosive, flammable, reactive, toxic, etc.) of the substance. This can sometimes be done by comparing the structure of the new substance with the structure of similar materials with known hazardous properties. If the chemical produced is of unknown composition, it must be assumed to be hazardous, and appropriate precautions should be taken.

If a chemical substance is produced for another user outside the University, the laboratory producing the substance is required to provide as much information as possible regarding the identity and known hazardous properties of the substance to the receiver of the material. Contact SUNUM Health and Safety Committee if you have questions or would like assistance in meeting this obligation.

4.2 TRAINING & INFORMATION

4.2.1 Chemical Safety Training

All students, faculty and lab associates exposed, or potentially exposed, to hazardous chemicals while performing their laboratory duties, must receive information and training regarding the standard, this Chemical Hygiene Plan, and laboratory safety prior to working with these chemicals. Training sessions arranged by SUNUM Health and Safety Committee are held regularly and are announced in the SUNUM web site at sunum.sabanciuniv.edu.

The content of the training programs will include the following:

- 1) Physical and health hazards of various classes of laboratory chemicals;

- 2) Methods/procedures for handling and safely using chemicals present in laboratories;
- 3) Appropriate response in the event of a chemical emergency (spill, overexposure, etc.);
- 4) University chemical hygiene policies; and
- 5) Applicable details of the University's Chemical Hygiene Plan.
- 6) Additional laboratory specific safety training is provided by the supervisor.

All students, faculty and lab associates working in the laboratory must receive this training prior to beginning work with hazardous chemicals. When a student, faculty or lab associate is to perform a non-routine task presenting hazards for which he or she has not already been trained, the Laboratory supervisor will be responsible for discussing with the student, faculty and lab associate the hazards of the task and any special measures (e.g. personal protective equipment or engineering controls) that should be used to protect him/her. SUNUM Health and Safety Committee are available to consult with the supervisor or Students, faculty and lab associates, as necessary.

Every laboratory worker should know the location and proper use of available protective clothing and equipment, and emergency equipment/procedures. Information on protective clothing and equipment is contained in Section 4.4 of this manual.

4.2.2 Chemical Safety Information Sources

There are numerous sources of chemical safety information on campus. These sources include:

- the labels found on containers of hazardous chemicals;
- the substance's Material Safety Data Sheet;

In addition, your Laboratory supervisor is available to provide safety information.

4.2.3 Container Labeling

All containers of hazardous chemicals which could pose a physical or health hazard to an exposed employee must be labeled clearly identifying their contents. Labels on purchased hazardous chemicals must not be removed or defaced except when empty. If you use secondary working containers that will take more than one work shift to empty, or if there is a chance that someone else will handle the container before you finish it, you must label it. This is part of your responsibility to help protect co-workers. The label and information must be in English and clearly and fully identify the contents. Many labels will provide you with additional safety information to help you protect yourself while working with this substance. This includes physical and health hazard warnings,

protective measures to be used when handling the material, clothing that should be worn, first aid instructions, storage information and procedures to follow in the event of a fire, leak or spill.

Read the label each time you use a newly purchased chemical. It is possible the manufacturer may have added new hazard information or reformulated the product since your last purchase, and thus altered the potential hazards you face while working with the product.

All employees involved in unpacking chemicals are responsible for inspecting each incoming container to insure that it is labeled with the information outlined above. Laboratory Supervisors should be notified if containers do not have proper labels.

4.2.4 Material Safety Data Sheet (MSDS)

A material safety data sheet (MSDS) is a form containing data regarding the properties of a particular substance. An important component of product stewardship and workplace safety, it is intended to provide workers and emergency personnel with procedures for handling or working with that substance in a safe manner, and includes information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill handling procedures.

The Material Data Safety Sheet is not always helpful in selecting appropriate safeguards in the laboratory. If you have questions about handling or protecting yourself from a particular chemical, contact the your supervisor or laboratory specialists.

4.2.4.1 What Is A Material Safety Data Sheet (MSDS)?

An MSDS is a written document produced by the chemical manufacturer or importer that includes important information about a chemical including:

- 1) The chemical identity
- 2) Physical and chemical characteristics
- 3) Physical and health hazards
- 4) Medical conditions which are aggravated by exposure to the chemical
- 5) The primary route(s) of entry into the body
- 6) Relevant exposure limits
- 7) Whether the hazardous chemical is listed in the [Annual Report on Carcinogens](#) by the [National Toxicology Program \(NTP\)](#) .

- 8) Precautions for safe handling
- 9) Procedures for clean-up of spills
- 10) Control measures
- 11) Emergency and first aid procedures
- 12) Date of preparation/update of the MSDS
- 13) Name, address and telephone number of the chemical manufacturer

For a detailed description of MSDS's view the [Hazard Communication Standard](#) - 1910.1200.¹⁶

4.2.4.2 Which Substances Do Not Require An MSDS?

MSDS's are not required for any of the following items or chemicals:

- Chemicals that are not considered by OSHA to be "hazardous". (Note: you will never get in trouble for having an MSDS you don't need, so it is always better to be safe than sorry.)
- ["Articles"](#) such as a carpet or chair.
- Hazardous waste as defined by the [Solid Waste Disposal Act of 1976](#) (a.k.a., RCRA, Title II, Subpart D).
- Hazardous substances defined in the [Comprehensive Environmental Response Compensation and Liability Act](#). (CERCLA).
- Pesticides defined in the [Federal Insecticide, Fungicide and Rodenticide Act](#) (FIFRA).
- Laboratory chemicals defined in [Occupational Exposure to Hazardous Chemicals in Laboratories](#). (Note: if you work in a laboratory and receive an MSDS when a chemical is shipped to you, you are required to retain the MSDS and make it available to Students, faculty and lab associatess.)
- Food and alcoholic beverages
- Tobacco or tobacco products
- Wood or wood products
- Cosmetics
- Nuisance particulates that do not pose any physical or health hazard
- Ionizing and non ionizing radiation
- Biological hazards

¹⁶ <http://www.safety.duke.edu/OHS/HazComFAQ.htm>

- Drugs in solid, final form for direct administration to the patient. (For example, tablets, pills, and capsules.)
- Drugs which are packaged by the chemical manufacturer for sale to consumers in retail establishments or those for personal consumption such as included in first aid cabinets. ¹⁷

¹⁷ <http://www.safety.duke.edu/OHS/HazComFAQ.htm>

4.3 STANDARD OPERATING PROCEDURES FOR WORKING WITH HAZARDOUS CHEMICALS

4.3.1 Chemical Handling Work Practices and Procedures

4.3.1.1 General Guidelines

Carefully read the label before using a chemical. The manufacturer's or supplier's Material Safety Data Sheet may also provide special handling information. Be aware of potential hazards existing in the laboratory and the appropriate safety precautions. Know the location and proper use of emergency equipment, the procedures for responding to emergencies, and the proper methods for storage, transport and disposal of chemicals within the facility.

- Try not to work alone in the laboratory. If you must work alone or in the evening, let someone else know and have them periodically check on you.
- Label all secondary chemical containers with appropriate identification and hazard information.
- Use only those chemicals for which you have the appropriate exposure controls (such as a chemical fume hood) and administrative programs/procedures (training, restricted access, etc.).
- Always use adequate ventilation with chemicals. Operations using volatile or toxic substances should be performed in a chemical fume hood.
- Use hazardous chemicals and all laboratory equipment only as directed or for their intended purpose.
- Inspect equipment or apparatus for damage before adding a hazardous chemical. Do not use damaged equipment.
- Inspect personal protective apparel and equipment for integrity or proper functioning before use.
- Malfunctioning laboratory equipment (such as a chemical fume hood) should be identified as "out of service" so that others will not inadvertently use it before repairs are made.
- Do not dispense more of a hazardous chemical than is needed for immediate use.

4.3.2 Personal Hygiene

- Remove contaminated clothing and gloves before leaving laboratory.
- Avoid direct contact with any chemical. Keep chemicals off your hands, face and clothing, including shoes. Never smell, inhale or taste a hazardous chemical. Wash thoroughly with soap and water after handling any chemical.
- Smoking, drinking, eating and the application of cosmetics is forbidden in laboratories where hazardous chemicals are used.
- Never pipette by mouth. Use a pipette bulb or other mechanical pipette filling device.

4.3.3 Housekeeping

- Keep floors clean and dry. Keep all aisles, hallways, and stairs clear of all chemicals. Stairways and hallways should not be used as storage areas.
- Keep all work areas, and especially work benches, clear of clutter and obstructions.
- All working surfaces should be cleaned regularly.
- Access to emergency equipment, utility controls, showers, eyewashes and exits should never be blocked.
- Label all containers used for storage of chemicals or working containers.
- Wastes should be kept in the appropriate containers and labeled properly.
- Any unlabeled containers are considered wastes at the end of each working day.

4.3.4 Glassware Safety

Handle and store laboratory glassware with care. Do not use damaged glassware. Borosilicate glassware is recommended for all laboratory glassware except for special experiments that use UV or other light sources. Any glass equipment to be evacuated, such as suction flasks, should be specially designed with heavy walls. Glass equipment in pressure or vacuum service should be provided with shielding to protect users and other laboratory occupants. Glass vessels at reduced pressure are capable of collapsing violently, either spontaneously (if cracked or weakened) or from an accidental blow. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them with safety netting to contain chemicals or fragments should implosion occur. Work with pressurized glass/plastic vessels or evacuated vessels require use of the following PPE: face shield, safety goggles or glasses depending on the substance in the vessel, long-sleeved lab coat, and closed toe shoes.

4.3.5 When Not To Proceed Without Reviewing Safety Procedures

Sometimes laboratory workers should not proceed with what seems to be a familiar task. Hazards may exist that are not fully recognized. Certain indicators should cause the employee to stop and review the safety aspects of their procedure. These indicators include:

- New procedure, process or test even if it is very similar to older practices.
- A change or substitution of any of the ingredient chemicals in a procedure.
- A substantial change in the amount of chemicals used (scale up of experimental procedures); usually one should review safety practices if the volume of chemicals used increases by 200%.
- A failure of any of the equipment used in the process, especially safeguards such as chemical fume hoods.
- Unexpected experimental results (such as a pressure increase, increased reaction rates, unanticipated by products). When an experimental result is different from the predicted, a review of how the new result may affect safety practices should be made.
- Chemical odors, illness in the laboratory staff that may be related to chemical exposures or other indicators of a failure in engineered safeguards.

The occurrence of any of these conditions should cause the researcher to pause, evaluate the safety implications of these changes or results, make changes as necessary and proceed cautiously. If needed, call the Lab Supervisor for assistance.

4.4 PROTECTIVE CLOTHING AND LABORATORY SAFETY EQUIPMENT

4.4.1 General Consideration - Personal Protective Clothing/Equipment

Personal protective clothing and equipment should be selected carefully and used after all feasible engineering and administrative controls have been put in place or while such controls are being established. These devices are viewed as less protective than other controls because they rely heavily on *each employee's work practices and training to be effective. The engineering and administrative* controls that should always be considered first when reducing or eliminating exposures to hazardous chemicals include:

- Substitution of a less hazardous substance or less hazardous equipment or process
- Scaling down size of experiment
- Isolation of the operator or the process
- Local and general ventilation (e.g., use of fume hoods)

A laboratory coat, gloves, protective eyewear, and closed toe shoes are required to be worn in SUNUM laboratories whenever handling hazardous chemicals. Additional personal protective equipment, such as face shield, utility gloves, aprons, and respirators, may be necessary depending on an assessment of the hazard and operation. Your Laboratory supervisor can assist you in determining the personal protective devices required for each task. Personal protective equipments will be supplied by SUNUM to employees.

4.4.2 Protection of Skin and Body

Skin and body protection involves wearing protective clothing over all parts of the body that could potentially become contaminated with hazardous chemicals. Personal protective equipment (PPE) should be selected on a task basis, and checked to ensure it is in good condition prior to use (e.g. no pinholes in gloves).

4.4.3 Standard Laboratory Clothing

Where there is no immediate danger to the skin from contact with a hazardous chemical it is still prudent to select clothing to minimize exposed skin surfaces in the laboratory. Employees shall not

wear shorts, short skirts or sandals in a laboratory. A laboratory coat with cuffs at the sleeves should be worn over street clothes and be laundered regularly. Laboratory coats are intended to prevent contact with dirt, chemical dusts and minor chemical splashes or spills. If it becomes contaminated it should be removed immediately and the affected skin surface washed thoroughly. Closed-toe shoes should be worn in the laboratory at all times.

4.4.4 Protective Clothing

The following guidelines for laboratory clothing are offered strictly from a safety standpoint.

- 1) Due to the potential for ignition, absorption, and entanglement in machinery, loose or torn clothing should be avoided unless wearing a lab coat.
- 2) Dangling jewelers and excessively long hair pose the same type of safety hazard.
- 3) Finger rings or other tight jewelers which is not easily removed should be avoided because of the danger of corrosive or irritating liquids getting underneath the piece and producing irritation.
- 4) Lab coats should be provided for protection and convenience. They should be worn at all times in the lab areas. Due to the possible absorption and accumulation of chemicals in the material, lab coats should not be worn in the lunchroom or elsewhere outside the laboratory.
- 5) Where infectious materials are present, closed (snapped) lab coats and gloves are essential.
- 6) Shoes shall be worn at all times in the laboratories. Sandals, open-toed shoes, and shoes with woven uppers, shall not be worn because of the danger of spillage of corrosive or irritating chemicals.
- 7) Care should be exercised in protective clothing selection; some protective clothing has very limited resistance to selected chemicals or fire.

Consult the MSDS for a chemical to find out the recommended clothing or PPE for a particular chemical. (Examples are latex, nitrile, or PVC gloves, or aprons.) ¹⁸

¹⁸ <http://ehs.okstate.edu/MODULES/PPE/Clothing.htm>

4.4.5 Aprons-- Rubber or Plastic

Some operations in the laboratory, like washing glassware, require the handling of relatively large quantities of corrosive liquids in open containers. To protect clothing in such operations, plastic or rubber aprons may be supplied.

A high-necked, calf- or ankle-length, rubberized laboratory apron or a long-sleeved, calf- or ankle-length, chemical- and fire-resistant laboratory coat should be worn anytime laboratory manipulation or experimentation is being conducted.

Always wear long-sleeved and long-legged clothing; do not wear short-sleeved shirts, short trousers, or short skirts. ¹⁹

4.4.6 Gloves

When handling chemicals, it is recommended that the correct gloves are used to protect the worker from accidental spills or contamination. If the gloves become contaminated they should be removed and discarded as soon as possible. There is no glove currently available that will protect a worker against all chemicals.

Protection of the hands when working with solvents, detergents, or any hazardous material is essential in the defense of the body against contamination. Exposure of the hands to a potentially hazardous chemical could result in burns, chafing of the skin due to extraction of essential oils ("defatting"), or dermatitis. The skin could also become sensitized to the chemical and once sensitized, could react to lesser quantities of chemicals than otherwise would have any effect. It is well documented that primary skin irritations and sensitizations account for significantly greater numbers of lost time incidents on the job than any other single type of industrial injury.

Proper selection of the glove material is essential to the performance of the glove as a barrier to chemicals. Several properties of both the glove material and the chemical with which it is to be used should influence the choice of the glove. Some of these properties include: permeability of the glove material, breakthrough time of the chemical, temperature of the chemical, thickness of the glove material, and the amount of the chemical that can be absorbed by the glove material (solubility effect). Glove materials vary widely in respect to these properties; for instance, neoprene

¹⁹ <http://ehs.okstate.edu/MODULES/PPE/Aprons.htm>

is good for protection against most common oils, aliphatic hydrocarbons, and certain other solvents, but is unsatisfactory for use against aromatic hydrocarbons, halogenated hydrocarbons, ketones, and many other solvents.

Gloves of various types are available and should be chosen for each specific job for compatibility and breakthrough characteristics. Excellent information is *Guidelines for the Selection of Chemical Protective Clothing* published by the American Conference of Governmental Industrial Hygienists (ACGIH).

4.4.6.1 Selection

For concentrated acids and alkalis, and organic solvents, natural rubber, neoprene or nitrile gloves are recommended. For handling hot objects, gloves made of heat-resistant materials (leather or Nomex) should be available and kept near the vicinity of ovens or muffle furnaces. A hot object should never be picked up with rubber or plastic gloves. Special insulated gloves should be worn when handling very cold objects such as liquid N₂ or CO₂. Do not use asbestos containing gloves. The following table (Table 2) offers a general guide to glove selection.

Glove Material	Intended Use	Advantages	Disadvantages
Latex exam style	Incidental Contact	<ul style="list-style-type: none"> • Good for biological and water-based materials • User acceptability 	<ul style="list-style-type: none"> • Poor for organic solvents • Hard to detect puncture holes • Latex allergy issues
Nitrile exam style	Incidental Contact	<ul style="list-style-type: none"> • Good for solvents, oils, greases, some acids and bases • Clear indication of tears and breaks • User acceptability 	<ul style="list-style-type: none"> • Slightly more expensive than latex
Utility style Nitrile – Solvex	Extended Contact	<ul style="list-style-type: none"> • Good for solvents, oils, greases, some acids and bases • Can be washed and reused 	<ul style="list-style-type: none"> • Not effective for halogenated and aromatic hydrocarbons

Neoprene – utility style	Extended contact	• Good for acids, bases alcohols, fuels, peroxides, hydrocarbons, and phenols	• Poor for halogenated and aromatic hydrocarbons
Butyl rubber utility gloves	Extended contact	• Good for ketones and esters	

Table 2 a general guide to glove selection

4.4.6.2 Usage

Before each use, gloves should be inspected for discoloration, punctures, and tears. Rubber and plastic gloves may be checked by inflating with air and submersing them in water to check for air bubbles.

Gloves should always be rinsed with a compatible solvent, soap and water prior to handling wash bottles or other laboratory fixtures. Do not blow into the gloves before put them on.

Before removal, gloves should be thoroughly washed, either with tap water or soap and water.

Students, faculty and lab associates shall remove gloves before leaving the immediate work site to prevent contamination of door knobs, light switches, telephones, etc. When gloves are removed, pull the cuff over the hand.²⁰

4.4.7 Eye Protection

Eye protection is mandatory in all areas where there is potential for injury. This applies not only to persons who work continuously in these areas, but also to persons who may be in the area only temporarily, such as maintenance or clerical personnel.

The type of eye protection required depends on the hazard. For most situations, safety glasses with side shields are adequate. Where there is a danger of splashing chemicals, goggles are required. More hazardous operations include conducting reactions that have potential for explosion and using

²⁰ <http://ehs.okstate.edu/MODULES/PPE/Gloves.htm>

or mixing strong caustics or acids. In these situations, a face shield or a combination of face shield and safety goggles or glasses should be used.

Plastic safety glasses should be issued to Students, faculty and lab associates who do not require corrective lenses.

For persons requiring corrective lenses, safety glasses ground to their prescription are available in a safety frame. Contact Environmental Health Services for additional information about availability. Please note that the wearing of safety glasses does not excuse the Students, faculty and lab associates from the requirement of wearing safety goggles.

It is recommended that contact lenses not be permitted in the laboratory. The reasons for this prohibition are:

1. If a corrosive liquid should splash in the eye, the natural reflex to clamp the eyelids shut makes it very difficult, if not impossible, to remove the contact lens before damage is done. The plastic used in contact lenses is permeable to some of the vapors found in the laboratory. These vapors can be trapped behind the lenses and can cause extensive irritation.
2. The lenses can prevent tears from removing the irritant. The protective goggles for use with contact lenses fit loosely around the eyes and have no vents for access by vapors. If chemical vapors contact the eyes while wearing contact lenses, these steps should be followed:
 - a) Immediately remove the lenses.
 - b) Continuously flush the eyes, for at least 15 to 30 minutes.
 - c) Seek medical attention.

Although safety glasses are adequate protection for the majority of laboratory operations, they are not sufficient for certain specific operations where there is danger from splashes of corrosive liquids or flying particles. Examples are: washing glassware in chromic acid solution, grinding materials, or laboratory operations using glassware where there is significant hazard of explosion or breakage (i.e., in reduced or excess pressure or temperature). In such cases, goggles or face shields shall be worn if there is need for protection of the entire face and throat.

If, despite all precautions, an Students, faculty and lab associates should experience a splash of corrosive liquid in the eye, the Students, faculty and lab associates is to proceed (with the assistance of a co-worker, if possible) to the nearest eyewash fountain and flush the eyes with water for at least 15 to 30 minutes. Flush from the eye outward. During this time, a co-worker should notify the proper authorities.

Visitors shall follow the same eye protection policy as Students, faculty and lab associates. If they do not provide their own eye protection, it is the laboratory's responsibility to provide adequate protection.²¹

4.4.8 Protection of the Respiratory System

Inhalation hazards can be controlled using ventilation or respiratory protection. Check the label and MSDS for information on a substance's inhalation hazard and special ventilation requirements.

When a potential inhalation hazard exists a substance's label or MSDS contains warnings such as:

- 1) Use with adequate ventilation
- 2) Avoid inhalation of vapors
- 3) Use in a fume hood
- 4) Provide local ventilation

Take appropriate precautions before using these substances. Controlling inhalation exposures via engineering controls (ventilation) is always the preferred method. As with other personal protective equipment, respiratory protection relies heavily on employee work practices and training to be effective.

²¹ <http://ehs.okstate.edu/MODULES/PPE/Eye.htm>

4.4.8.1 Use Of Respirators

Respirators are designed to protect against specific types of substances in limited concentration ranges. Respirators must be selected based on the specific type of hazard (toxic chemical, oxygen deficiency, etc.), the contaminant's anticipated airborne concentration, and required protection factors. Types of respiratory protective equipment include:

- Disposable NPR95 or HEPA filter masks (particle-removing respirators)
- Air purifying respirators (vapor, gas and/or particle removing – ½ mask, full face, or powered air purifying (PAPR))
- Atmosphere supplying respirators (air line or SCBA)

4.5 LABORATORY SAFETY EQUIPMENT

4.5.1 Chemical Fume Hoods

In the laboratory the chemical fume hood is the primary means of controlling inhalation exposures. Hoods are designed to retain vapors and gases released within them, protecting the laboratory worker's breathing zone from the contaminant. Chemical fume hoods can also be used to isolate apparatus or chemicals that may present physical hazards to employees. The closed sash on a hood serves as an effective barrier to fires, flying objects, chemical splashes or spattering and small implosions and explosions.

There are a wide variety of fume hood styles and systems on campus including constant volume, variable air volume, and auxiliary air systems. Many of these systems have been modified with energy-saving setbacks. These setbacks are triggered by a variety of methods including sash position, motion sensors, and room light switches, many in conjunction with time of day.

Most constant air volume systems are on hoods that have a bypass design over the sash. These use the most energy because they operate on the idea of a constant volume of air being exhausted through the hood, regardless of sash height. The majority of older fume hood systems on campus are bypass hoods with constant air volume systems. With these hoods, the safe sash height is indicated by red arrows and the sash should stay in that position. Those with sash height setbacks for energy savings are marked indicating the setback sash location.

Variable air volume systems use less energy than constant air volume systems because they are designed so that the face velocity stays the same but the volume of air exhausted is lowered as the sash is lowered. The sashes on these hoods should be kept as low as possible when not actively working in the hood. Some of these systems are supplemented with motion sensors that lower flow rates when someone is not working at the hood.

When using a chemical fume hood keep the following principles of safe operation in mind:

- 1) Make sure it is switched on.
- 2) Make sure that airflow indicator is within spec.
- 3) Keep all chemicals and apparatus at least six inches inside the hood behind the sash.
- 4) Hoods are not intended for storage of chemicals and materials stored in them should be kept to a minimum. Stored chemicals should not block vents or alter airflow patterns
- 5) For variable air volume hoods, keep the hood sash lowered when not manipulating chemicals or adjusting apparatus within the hood.
- 6) If the alarm sounds, stop work and seek help.

- 7) Work over a spill tray if possible, when you are doing tasks which could lead to a spillage, e.g. decanting wastes.
- 8) Beware of incompatible chemicals mixing, especially in wastes.

Follow the chemical manufacturers or supplier's specific instructions for controlling inhalation exposures with ventilation when using their products. These instructions are located on the MSDS and/or label. It is recommended that all work involving volatile or higher hazard chemicals be conducted inside a chemical fume hood whenever feasible. However, manipulations of very small microliter volumes of hazardous chemicals may be conducted on the bench top if necessary. Contact your lab supervisor with any questions or concerns regarding engineering controls for specific operations.

4.5.2 Eyewashes and Safety Showers

Whenever chemicals have the possibility of damaging the skin or eyes, an emergency supply of water must be available. All laboratories in which hazardous chemicals are handled and could contact the eyes or skin resulting in injury should have ready access to plumbed eyewash stations and safety showers. To ensure easy access and safe use of eyewashes and safety showers: Figure 6



Figure 6 Eyewashes and Safety Showers

- Keep all passageways to eyewashes and safety showers clear of any obstacle. This includes even temporary storage of supplies, carts, etc.
- Ensure that you and all laboratory personnel know the location of the nearest eyewashes and safety showers, and how to operate them.
- Eyewashes should be checked routinely by laboratory personnel to be certain that water flows through it. Allow them to run for several minutes once per week to clear out the supply lines.

- Showers should be checked routinely by laboratory personnel to assure that access is not restricted and that the start chain or lever is within reach.
- The safety showers and eyewashes are tested annually by SUNUM to ensure proper operation and sufficient flow rates.

4.5.3 Fire Safety Equipment

Fire safety equipment should be easily accessible to the laboratory and it must include the appropriate fire extinguisher(s) and may include fire hoses, fire extinguishers, preaction sprinkler systems, as determined by SUNUM.

4.6 CHEMICAL PROCUREMENT, DISTRIBUTION, AND STORAGE

4.6.1 Procurement

Before a new substance that is known or suspected to be hazardous is received, those individuals who will handle it should have information on proper handling, storage, and disposal. It is the responsibility of the principal investigator or the supervisor to ensure that the laboratory facilities in which the substance will be handled are adequate and that those who will handle the substance have received the proper information and training. The necessary information on proper handling of hazardous substances can be obtained from the Material Safety Data Sheets which are provided by the vendor. Order the smallest amount of chemical needed where possible. No container should be accepted without an adequate identifying label as outlined in Section 4.2.3 of this manual. Every chemical to be used at SUNUM should be approved by Laboratory Supervisor before ordering. The following chemicals require SUNUM approval prior to purchase:

Highly Toxic Compressed Gases:

Arsine	Fluorine	Hydrogen cyanide	Nitrogen tetroxide
Cyanogen	Germane	Hydrogen selenide	Phosgene
Cyanogen chloride	Nitric oxide	Phosphine	Diborane
Hexaethyl tetraphosphate			

OSHA Substance-Specific Standards

Arsenic and arsenic compounds	Ethylene oxide
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Air/Moisture Reactives:

Barium	Lithium	Phosphorus	Rubidium
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Cesium
Sodium

Lithium aluminum hydride

Potassium

Others:

Benzoyl peroxide Hydrogen (compressed gas)

CDC Select Agents

Cyanide compounds

Perchloric acid

Uranyl acetate or nitrate

Hydrofluoric acid

Picric acid

4.6.2 Distribution

All containers of hazardous chemicals should be transported in a secondary container such as a chemical carrier. These carriers are commercially available and provide both secondary containment as well as "bump" protection. If several bottles must be moved at once, the bottles should be transported on a small cart with a substantial rim to prevent slippage from the cart. Wherever available, a freight elevator should be used to transport chemicals from one floor to another. The stockrooms will not allow you to purchase hazardous liquids from the stockroom if you do not have a chemical carrier with you to bring it back to your laboratory.

4.6.3 Chemical Storage in the Laboratory

Carefully read the label before storing a hazardous chemical. The MSDS will provide any special storage information as well as information on incompatibilities. *Do not store unsegregated liquid chemicals in alphabetical order. Do not store incompatible chemicals in close proximity to each other.*

- 1) All bottles should not be filled higher than shoulder-they have been known to explode.
- 2) Waste bottles should be no more than two thirds full, and the cap should be slackened off.
- 3) Keep no more than 500ml on the benchtop.
- 4) Keep larger amounts in metal cabinets with door shut.
- 5) Never put them into fridges or freezers that are not spark-proof.
- 6) Separate hazardous chemicals in storage as follows:

Solids: - oxidizers

- Flammable solids (phosphorus, magnesium, lithium)
- Water reactives
- Others

Liquids: - flammable/combustible

- Inorganic acids
- Organic acids
- Caustics
- Oxidizers

Gases: - toxic

- Oxidizers
- Flammable

Once separated into the above hazard classes, chemicals may be stored alphabetically.

Use approved storage containers and safety cans for flammable liquids. It is preferable to store flammable chemicals in flammable storage cabinets. No greater than 2,5 Lt of flammable liquids may be kept outside of rated flammable storage cabinets in any laboratory. *Flammable chemicals requiring refrigeration should be stored only in the refrigerators and freezers specifically designed for flammable storage.*

Hazardous chemicals should not be stored on bench tops, on the floor, or in hoods. Chemicals should also not be stored under sinks, if possible. If separate cabinets are not feasible, chemicals of different chemical classes can be segregated by placing them in trays. Corrosive or hazardous liquids should not be stored above eye level.

Use secondary containers for highly corrosive or toxic chemicals.

Avoid exposure of chemicals while in storage to heat sources (especially open flames) and direct sunlight.

Conduct periodic inventories of chemicals stored in the laboratory and dispose of old or unwanted chemicals promptly in accordance with hazardous chemical waste disposal procedures

Assure all containers are properly labelled with the identity of the contents and any appropriate hazard warnings.

For more information on chemical storage, contact your Lab supervisor.

4.6.4 Chemical Storage-Chemical Stability

Stability refers to the susceptibility of a chemical to dangerous decomposition. The label and MSDS will indicate if a chemical is unstable.

Special note: peroxide formers - Ethers, liquid paraffin's, and olefins form peroxides on exposure to air and light. Peroxides are extremely sensitive to shock, sparks, or other forms of accidental ignition and can be even more sensitive than primary explosives such as TNT. Since many of these chemicals are packaged in an air atmosphere, peroxides can form even though the containers have not been opened. All containers of ether or other peroxide formers should be dated upon receipt and discarded by the expiration date on the container. If the container does not have an expiration date but the chemical is a peroxideformer, the container should be discarded after one (1) year of receipt, even if unopened. Highly Reactive Chemicals and High Energy Oxidizers for additional information on storage limitations and examples of materials which may form explosive peroxides.

For additional information on chemical stability, contact your laboratory supervisor.

4.6.5 Chemical Storage-Incompatible Chemicals

Certain hazardous chemicals should not be mixed or stored with other chemicals because a severe reaction can take place or an extremely toxic reaction product can result. The label and MSDS will contain information on incompatibilities and should always be consulted. The following table contains examples of incompatible chemicals, but is not a complete list: Table 3

CHEMICAL	KEEP OUT OF CONTACT WITH
Acetic Acid	Chromic acid, nitric acid hydroxyl compounds, ethylene, glycol, perchloric acid, peroxides, permanganates
Acetone	Concentrated nitric and sulphuric acid mixtures
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali Metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, the halogens
Ammonia, anhydrous	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium Nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulphur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent

Azides	Acids
Bromine	Same as chlorine
Calcium Oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents.
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organic or combustible materials
Chromic Acid	Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids in general
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Chlorine Dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cumene Hydroperoxide	Acids, organic or inorganic
Cyanides	Acids
Flammable Liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic Acid	Nitric acid, alkali
Hydrofluoric Acid	Ammonia, aqueous or anhydrous
Hydrogen Peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidizing gases
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases, acetylene, ammonia (aqueous or anhydrous), hydrogen
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitrates	Sulfuric acid
Nitric Acid(concentrated)	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic Acid	Silver, mercury
Oxygen	Oils, grease, hydrogen; flammable liquids, solids, or gases

Perchloric Acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorus (white)	Air, oxygen, alkalies, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium Chlorate	Sulfuric and other acids
Potassium Permanganate	Glycerin, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium Peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric Acid	Potassium chlorate, potassium perchlorate, potassium permanganate (or compounds with similar light metals, such as sodium, lithium, etc.)

(From Manufacturing Chemists' Association, Guide for Safety in the Chemical Laboratory, pp. 215-217.)

Table 3 Incompatible chemicals

4.6.6 Transportation of Hazardous Materials and Chemicals

- 1) Use safety carriers to move chemical containers made of glass a significant distance.
- 2) Transport large bottles of corrosives in corrosive resistant safety carriers.
- 3) When moving several glass containers at one time:
 - transport the bottles on a low, stable cart with a substantial rim around the edge,
 - transport the bottles on a cart inside a secondary container which can hold the volume of their contents,
- 4) Segregate chemicals by reactive groups into separate secondary containers.
- 5) Prevent bottles from knocking against each other.
- 6) When transporting chemicals from one floor to another, take the freight elevator if possible.
- 7) Transport gas cylinders with the safety cap in place and using a two-wheeler designed for this purpose. Table 4

Proper identification and classification of the material	For example: Flammable liquids, toxic, n.o.s., 3, UN1992, PGI,(acetonitrile,methanol)
Choosing appropriate, certified packaging	

Completing the required shipping documents	
Affixing the appropriate, required labels/markings	
Arranging for qualified shipping company	

Table 4 Transportation of Hazardous Materials and Chemicals

4.7 HEALTH AND SAFETY INFORMATION FOR WORK WITH CHEMICALS OF SPECIFIC HAZARDS

4.7.1 Safety in the Operation of Laboratory Reactors and Pressure Vessel

When dealing with hot equipment the following precautions should be considered:

- Allow the hot equipment or object to cool down whenever possible before handling.
- Wear appropriate personal protective equipment such as face shield, heat resistant gloves etc.
- Keep flammable or combustible substances away from hot equipment or object.
- Display a “HOT!” sign next to the hot equipment to warn others.
- Do not place a glass thermometer inside a muffle.

4.7.1.1 Dealing With High Pressure Reactors And Vessels

4.7.1.1.1 The User’s Responsibility

The basic responsibility for safety when using a pressure vessel rests entirely with the user, who must...

A. Select a reactor or pressure vessel which has the capacity, pressure rating, corrosion resistance and design features that are suitable for its intended use. All pressure vessels employed are designed for operation within certain temperature and pressure limits, using gaskets, closures and other elements carefully selected for safe operation within the limits specified for that design. But in order to preserve the validity of these designs, all temperature and pressure limits must be observed, and no attempt should be made to increase these limits by making alterations or by substituting components which are not recommended by the manufacturer.

B. Install and operate the equipment within suitable barricade, if required, using appropriate safety accessories and operating in full compliance with local safety codes and rules.

C. Establish training procedures to ensure that any person handling the equipment knows how to use it properly.

D. Maintain the equipment in good condition and establish procedures for periodic testing to be sure that the vessel remains structurally sound.

Consider the Chemistry

Since safety in bench scale pressure reactions is so closely related to the chemistry involved in any process, there are several basic questions that the operator must always consider before starting to use pressure equipment: Is the reaction exothermic?

What by-products will be produced and what will be their behavior? What maximum temperature and pressure limits will be observed? Under what circumstances (temperature, pressure and catalyzing agents) might the reaction run out of control? By considering these and any other related safety questions before starting a pressure operation, the user should be able to anticipate any violent chemical behavior and take steps to prevent it.

Reactions involving highly reactive compounds such as acetylene, butadiene, dioxane, ethylene oxide, oxygen and all strong oxidizing agents, must be handled cautiously. Close attention must also be given to any reactions that might release sudden surges of heat and pressure and to any by-products or end-products suspected to have explosive or detonating properties. It is always advisable to run preliminary experiments using small volumes of reactants when starting work with new or unfamiliar materials. The amounts can be increased later after it has been shown that the reaction proceeds smoothly with no indication of erratic or explosive behaviour.

While dealing with potential explosive materials, a great deal of care should be taken. Below some explosive groups are listed

Atomic Groupings that Characterize Explosive Compounds: Figure 7

Acetylide	$\text{—C}\equiv\text{C—Metal}$
Amine oxide	$\begin{array}{c} \oplus \quad \ominus \\ \diagup \quad \diagdown \\ \text{—N—O} \\ \diagdown \quad \diagup \end{array}$
Azide	$\text{—N}=\text{N}=\text{N}$
Chlorate	—ClO_3
Diazo	$\text{—N}=\text{N—}$
Diazonium	$(\text{—N}\equiv\text{N})^{\oplus}\text{X}^{\ominus}$
Fulminate	$\text{—O}=\text{N}=\text{C}$
N-Haloamine	$\begin{array}{c} \text{Cl} \\ \\ \text{—N—} \\ \\ \text{X} \end{array}$
Hydroperoxide	—O—O—H
Hypohalite	—O—X
Nitrate	—O—NO_2
Nitrite	—O—NO
Nitro	—NO_2
Nitroso	—NO
Ozonide	$\begin{array}{c} \text{O} \quad \text{O} \\ \diagdown \quad \diagup \\ \text{—O—} \end{array}$
Peracid	$\begin{array}{c} \text{O} \\ \\ \text{—C—O—O—H} \end{array}$
Perchlorate	—ClO_4
Peroxide	—O—O—

Figure 7 Atomic Groupings

Barricades and Ventilation

The room in which a pressure reactor is to be operated must be well ventilated. This is particularly important when working with flammable or toxic materials. The reactors should be located close to a laboratory hood or exhaust fan so that any released gases can be discharged safely. There should be no open flames in adjacent areas.

In case of an accident or unexpected over-pressure, the safety rupture disc should burst to relieve the vessel before it is damaged by excess pressure. Therefore provisions must be made to handle the noise and fume hazards created by this release. Extension piping attached to the safety rupture disc and leading to an appropriate discharge area offers the best protection against this possibility. Ear protection is also recommended, since the loud report produced by a bursting rupture disc may damage the hearing of anyone standing near the reactor.

It must also be remembered that certain explosive reactions proceed with such speed that the shock wave created by the explosion may damage the vessel before the rupture disc can dump the excess pressure. The best protection against this hazard is to operate the reactor behind a suitable barricade or in a pressure test cubicle or cell.

If a barricade is required it should be built of concrete, brick or steel in whatever thickness or form is considered necessary to protect the operator from flying fragments if the apparatus should explode. Glass shields, either plain or reinforced with wire mesh, are not recommended. The requirements for barricades differ so widely that each should be designed and built in order to protect against the potential hazards inherent in each installation.

4.7.1.1.2 Loading Limits

One of the most subtle and frequently overlooked hazards that can arise in pressure vessel operation is that produced by overfilling the vessel. A vessel must never be filled to more than three-fourths of its available free space, and in some cases the charge must be reduced even further for safe operation. Dangerous pressures can develop suddenly when a liquid is heated in a closed vessel if the available free space is not sufficient to accommodate the expanding the liquid. This is particularly true of water and water solutions which may increase to as much as three times their initial volume when heated from room temperature to the critical point at 374 °C. If the free space in the vessel is not sufficient to accommodate this expansion, destructive pressures will develop very suddenly and unexpectedly.

Although this problem can arise when heating any fluid, it is particularly dangerous when working with water, as shown by the data tabulated below. At temperatures up to 200 °C the increase in volume is small. But as temperature is raised higher, the fluid expands to fill 150% of its original space at 321 °C, and to more than three times its original space at the 374 °C critical point.

To prevent damage from this type of expansion, the amount of water placed in any sealed pressure vessel should not exceed the volume determined from the following formula for Maximum

Allowable Water Loading (MAWL):

$$\text{MAWL} = (0.9) * (\text{Vessel Volume}) / \text{Volume Multiplier at Max. Temp.}$$

Example:

What is the maximum volume of water slurry which can be treated safely to 300 °C in a 1000 mL vessel?

Substituting in the above formula:

$$\text{MAWL} = (0.9) * (1000) / 1.4 = 643 \text{ mL}$$

From the above it is clear that the vessel should not be charged with more than 643mL of slurry at room temperature. Good practice would dictate that the charge should be held somewhat below this theoretical maximum.

Liquid Volumes and Vapor Pressures for Water in a Closed Vessel at Elevated Temperatures

Table 5

Temperature		Specific Volume of the Liquid	Vapor Pressure	Volume Multiplier	Volume Increase
°F	°C	cu.ft./lb.	psig (Gauge)	Sp. V _T /Sp. V _{77F}	%
77	25	0.01607	-	1.00	0
212	100	0.01672	0	1.04	4
392	200	0.01853	211	1.15	15
482	250	0.0201	562	1.25	25
540	282	0.0215	948	1.34	34
572	300	0.0225	1230	1.40	40
610	321	0.0241	1650	1.50	50
660	349	0.0278	2350	1.73	73
685	363	0.0315	2780	1.96	96
700	371	0.0369	3070	2.30	130
702	372	0.0385	3120	2.40	140
704	373	0.0410	3160	2.55	155
705	374	0.0503	3190	3.13	213

Table 5 Liquid Volumes and Vapor Pressures for Water in a Closed Vessel at Elevated Temperatures

4.7.1.1.3 Pressure and Temperature Limits

The maximum pressure and temperature at which any reactor or pressure vessel can be used will depend upon the design of the vessel and the materials used in its construction. Since all materials lose strength at elevated temperatures, any pressure rating must be stated in terms of the temperature at which it applies. For commercial vessels, the given limits should not be exceeded. For manufactured vessels the formula below can be used, but it should be reminded that for such

devices safety factors must be kept as high as possible. Also the formula below is for obtaining an idea. The user should always consult to a specialist on that subject.

The maximum allowable working pressure (MAWP) of a steam boiler is an absolute restriction of pressure within psig unit for a steam boiler is allowed to run. The ASME BPV Code (American Society of Mechanical Engineers Boiler and Pressure Vessel) says that absolutely no steam boiler should be run at a pressure above the MAWP with the exception of the safety valve is operated to discharge excessive pressure. MAWP on the header or drum can be calculated based on the equation below:

$$\text{MAWP} = (t \times E \times \text{TS}) / (R \times \text{SF})$$

Abbreviation of the equation above is:

MAWP = Maximum Allowable Working Pressure in the drum or header.

E = Joint efficiency of welding in the drum or header (= 1 for machined or seamless vessel)

t = Thickness of header or drum

TS = Tensile strength of the material, (for SS it can be assumed to be 70×10^3 psi)

SF = Design safety factor, the value which is commonly used is five

R = Inside radius of header or drum either steam drum or water drum

Example:

What is the MAWP of a stainless steel reactor with 5 mm thickness and 50 mm inner radius?

For such a reactor, it can be assumed that it is seamless.

$$\text{MAWP} = (5 \text{ mm} \times 1 \times 70 \times 10^3 \text{ psi}) / (50 \text{ mm} \times 5) = 1400 \text{ psi} = 1385.3 \text{ psig (at sea level)}$$

4.7.1.1.4 Maintenance and Training

The user must realize that it is his responsibility to keep his reactor in good condition and to use it only within the prescribed temperature and pressure limits. He must be constantly aware of the serious consequences that can result from such things as: opening the wrong valve, mixing combustible vapours with air or oxidizing gases, adding reactants too fast or failing to observe and prevent a sudden increase in temperature or pressure. Supervisors should make frequent checks to be sure that all safety rules are being observed. In the absence of a supervised safety program the user must take time to become completely familiar with his equipment and to consider any hazards inherent in the reactions he intends to perform.

4.7.1.1.5 Materials of Construction

Although most reactors and pressure vessels are made of stainless steel, which are suitable for most of the applications, there are many operations which require pressure vessels made of other metals or alloys. Each of these alloys has its own physical strength and temperature characteristics, as well as its own unique resistance to certain corrosive agents.

Stainless Steel is an excellent material for use with most organic systems. A few organic acids and organic halides can, under certain conditions, hydrolyze to acetic, formic and other organic acids that are routinely handled in stainless steel. Stainless steel is not normally the material of choice for inorganic acid systems. At ambient temperatures it does offer useful resistance to dilute sulphuric, sulphurous, phosphoric and nitric acids which readily attack stainless steel in higher concentrations and temperatures. Halogen acids attack all forms of stainless steel rapidly, even at low temperatures and in dilute solutions. Stainless steel offers excellent resistance to surface corrosion by caustics, but this is misleading. Caustics can cause stress corrosion cracking in stainless pressure vessels. This phenomenon begins to appear at temperatures just above 100 °C and has been the most common cause of corrosion failure in stainless laboratory vessels. Stainless steel does offer good resistance to ammonia and to most ammonia compounds.

Halogen salts can cause severe pitting in all stainless steels. Chlorides can cause stress corrosion cracking, but many other salt solutions can be handled in stainless vessels, particularly neutral or alkaline salts. At moderate temperatures and pressures, stainless steel can be used with most commercial gases. In a scrupulously anhydrous system even hydrogen chloride, hydrogen fluoride and chlorine can be used in stainless steel.

4.7.2 FLAMMABLE LIQUIDS

Flammable liquids are among the most common of the hazardous materials found in laboratories. They are usually highly volatile (have high vapor pressures at room temperature) and their vapors, mixed with air at the appropriate ratio, can ignite and burn. By definition, the lowest temperature at which they can form an ignitable vapor/air mixture (the flash point) is less than 37.8°C (100°F) and for many common laboratory solvents (ether, acetone, toluene, acetaldehyde) the flash point is well below room temperature.

As with all solvents, their vapor pressure increases with temperature and, therefore, as temperatures increase they become more hazardous. For a fire to occur, three distinct conditions must exist simultaneously:

- (1) the concentration of the vapor must be between the upper and lower flammable limits of the substance (the right fuel/air mix); (2) an oxidizing atmosphere, usually air, must be available; and (3) a source of ignition must be present.

Removal of any of these three conditions will prevent the start of a fire. Flammable liquids may form flammable mixtures in either open or closed containers or spaces (such as refrigerators), when leaks or spills occur in the laboratory, and when heated.

Strategies for preventing ignition of flammable vapors include removing all sources of ignition or maintaining the concentration of flammable vapors below the lower flammability limit by using local exhaust ventilation such as a hood. The former strategy is more difficult because of the numerous ignition sources in laboratories. Ignition sources include open flames, hot surfaces, operation of electrical equipment, and static electricity.

The concentrated vapors of flammable liquids are usually heavier than air and can travel away from a source for a considerable distance (across laboratories, into hallways, down elevator shafts or stairways).

If the vapors reach a source of ignition a flame can result that may flash back to the source of the vapor. The danger of fire and explosion presented by flammable liquids can usually be eliminated or minimized by strict observance of safe handling, dispensing, and storing procedures.

4.7.3 HIGHLY REACTIVE CHEMICALS & HIGH ENERGY OXIDIZERS

Highly reactive chemicals include those which are inherently unstable and susceptible to rapid decomposition as well as chemicals which, under specific conditions, can react alone or with other substances in a violent uncontrolled manner, liberating heat, toxic gases, or leading to an explosion. Reaction rates almost always increase dramatically as the temperature increases. Therefore, if heat evolved from a reaction is not dissipated, the reaction can accelerate out of control and possibly result in injuries or costly accidents.

Air, light, heat, mechanical shock (when struck, vibrated or otherwise agitated), water, and certain catalysts can cause decomposition of some highly reactive chemicals, and initiate an explosive reaction.

Hydrogen and chlorine react explosively in the presence of light. Alkali metals, such as sodium, potassium and lithium, react violently with water liberating hydrogen gas. Examples of shock sensitive materials include acetylides, azides, organic nitrates, nitro compounds, and many peroxides.

Organic peroxides are a special class of compounds that have unusual stability problems, making them among the most hazardous substances normally handled in the laboratories. As a class, organic peroxides are low powered explosives. Organic peroxides are extremely sensitive to light, heat, shock, sparks, and other forms of accidental ignition; as well as to strong oxidizing and reducing materials. All organic peroxides are highly flammable.

Peroxide formers can form peroxides during storage and especially after exposure to the air (once opened). Peroxide forming substances include: aldehydes, ethers (especially cyclic ether), compounds containing benzylic hydrogen atoms, compounds containing the allylic structure (including most alkenes), vinyl and vinylidene compounds.

4.7.4 COMPRESSED GAS SAFETY

4.7.4.1 Compressed Gases

Compressed gases can be toxic, flammable, oxidizing, corrosive, inert or a combination of hazards. In addition to the chemical hazards, compressed gases may be under a great deal of pressure. The amount of energy in a compressed gas cylinder makes it a potential rocket. Appropriate care in the handling and storage of compressed gas cylinders is essential.

4.7.4.2 Hazards

The following is an overview of the hazards to be avoided when handling and storing compressed gases:

- **Asphyxiation:** Simple asphyxiation is the primary hazard associated with *inert gases*. Because inert gases are colorless and odorless, they can escape into the atmosphere undetected and quickly reduce the concentration of oxygen below the level necessary to support life. The use of oxygen monitoring equipment is strongly recommended for enclosed areas where inert gases are being used.
- **Fire and Explosion:** Fire and explosion are the primary hazards associated with *flammable gases, oxygen and other oxidizing gases*. Flammable gases can be ignited by static electricity or by a heat source, such as a flame or a hot object. [Oxygen](#) and other oxidizing gases do not burn, but will support combustion of organic materials. Increasing the concentration of an oxidizer accelerates the rate of combustion. Materials that are nonflammable under normal conditions may burn in an oxygen-enriched atmosphere.
- **Chemical Burns:** *Corrosive gases* can chemically attack various materials, including fire-resistant clothing. Some gases are not corrosive in their pure form, but can become extremely destructive if a small amount of moisture is added. Corrosive gases can cause rapid destruction of skin and eye tissue.
- **Chemical Poisoning:** Chemical poisoning is the primary hazard of *toxic gases*. Even in very small concentrations, brief exposure to these gases can result in serious poisoning injuries. Symptoms of exposure may be delayed.
- **High Pressure:** All compressed gases are potentially hazardous because of the high pressure stored inside the cylinder. A sudden release of pressure can cause injuries by propelling a cylinder or whipping a line.

- **Cylinder Weight:** A full size cylinder may weigh more than 130 pounds. Moving a cylinder manually may lead to back or muscle injury. Dropping or dragging a cylinder could cause serious injury.

4.7.4.3 Handling Precautions

- Avoid dropping, dragging or sliding cylinders. Use a suitable hand truck or cart equipped with a chain or belt for securing the cylinder to the cart, even for short distances.
- Do not permit cylinders to strike each other violently. Cylinders should not be used as rollers for moving material or other equipment.
- Cylinder caps should be left on each cylinder until it has been secured against a wall or bench or placed in a cylinder stand, and is ready for installation of the regulator. Cylinder caps protect the valve on top of the cylinder from damage if knocked.
- Never tamper with pressure relief devices in valves or cylinders.
- Use only wrenches or tools provided by the cylinder supplier to remove a cylinder cap or to open a valve. Never use a screwdriver or pliers.
- Keep the cylinder valve closed except when in use.
- Position cylinders so that the cylinder valve is accessible at all times.
- Use compressed gases only in a well-ventilated area. Toxic, flammable and corrosive gases should be carefully handled in a hood or gas cabinet. Proper containment systems should be used and minimum quantities of these products should be kept on-site.
- When discharging gas into a liquid, a trap or suitable check valve should be used to prevent liquid from getting back into the cylinder or regulator.
- Where more than one type of gas is in use, label gas lines. This is particularly important when the gas supply is not in the same room or area as the operation using the gases.
- Do not use the cylinder valve itself to control flow by adjusting the pressure.

4.7.4.4 Storage Of Compressed Gas Cylinders

- 1) All cylinders must be secured to a wall, bench or fixed support using a chain or strap placed 2/3 of the way up. Cylinder stands are an alternative to straps.
- 2) Cylinders should be strapped individually.
- 3) Do not store full and empty cylinders together.
- 4) Oxidizers and flammable gases should be stored in areas separated by at least 20 feet or by a noncombustible wall.

- 5) Cylinders should not be stored near radiators or other heat sources. If storage is outdoors, protect cylinders from weather extremes and damp ground to prevent corrosion.
- 6) No part of a cylinder should be subjected to a temperature higher than 50°C. A flame should never be permitted to come in contact with any part of a compressed gas cylinder.
- 7) Do not place cylinders where they may become part of an electric circuit.
- 8) Keep the number of cylinders in a laboratory to a minimum to reduce the fire and toxicity hazards.
- 9) Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed or discarded if at atmospheric pressure.
- 10) Ensure that the cylinder is properly and prominently labeled as to its contents.
- 11) NEVER place acetylene cylinders on their side.

4.7.4.5 Using Compressed Gas Cylinders

Before using cylinders, read all label information and [Material Safety Data Sheets](#) (MSDSs) associated with the gas being used. The cylinder valve outlet connections are designed to prevent mixing of incompatible gases. The outlet threads vary in diameter; some are internal and some are external; some are right-handed and some are left-handed. Generally, right-handed threads are used for fuel gases.

To set up and use the cylinder, follow these steps:

1. Attach the closed regulator to the cylinder. **Never open the cylinder valve unless the regulator is completely closed.** Regulators are specific to the gas involved. A regulator should be attached to a cylinder without forcing the threads. If the inlet of a regulator does not fit the cylinder outlet, no effort should be made to try to force the fitting. A poor fit may indicate that the regulator is not intended for use on the gas chosen.
2. Turn the delivery pressure adjusting screw counter-clockwise until it turns freely. This prevents unintended gas flow into the regulator.
3. Open the cylinder **slowly** until the inlet gauge on the regulator registers the cylinder pressure. If the cylinder pressure reading is lower than expected, the cylinder valve may be leaking.
4. With the flow control valve at the regulator outlet closed, turn the delivery pressure adjusting screw clockwise until the required delivery pressure is reached.
5. Check for leaks using *Snoop* or soap solution. At or below freezing temperatures, use a glycerin and water solution, such as *Snoop*, rather than soap. Never use an open flame to detect leaks.

6. When finished with the gas, close the cylinder valve and release the regulator pressure.

4.7.4.6 Assembly Of Equipment And Piping

- Do not force threads that do not fit exactly.
- Use Teflon tape or thread lubricant for assembly. Teflon tape should only be used for tapered pipe thread, not straight lines or metal-to-metal contacts.
- Avoid sharp bends of copper tubing. Copper tubing hardens and cracks with repeated bending.
- Inspect tubing frequently and replace when necessary.
- Tygon and plastic tubing are not appropriate for most pressure work. These materials can fail under pressure or thermal stress.
- Do not mix different brands and types of tube fittings. Construction parts are usually not interchangeable.
- Do not use oil or lubricants on equipment used with [oxygen](#).
- Do not use copper piping for [acetylene](#).
- Do not use cast iron piping for [chlorine](#).

4.7.4.7 Leaking Cylinders

Most leaks occur at the valve in the top of the cylinder and may involve the valve threads valve stem, valve outlet, or pressure relief devices. Lab personnel should not attempt to repair leaking cylinders.

Where action can be taken without serious exposure to lab personnel:

1. Move the cylinder to an isolated, well-ventilated area (away from combustible materials if the cylinder contains a flammable or oxidizing gas).
2. Contact Laboratory Specialists.

Whenever a large or uncontrollable leak occurs, evacuate the area and immediately contact with Campus Safety or SUNUM Facilities Management.

4.7.4.8 Empty Cylinders

- 1) Remove the regulator and replace the cylinder cap.
- 2) Mark the cylinder as empty or MT and store in a designated area for return to the supplier.
- 3) Do not store full and empty cylinders together.

- 4) Do not have full and empty cylinders connected to the same manifold. Reverse flow can occur when an empty cylinder is attached to a pressurized system.
- 5) Do not refill empty cylinders. Only the cylinder supplier should refill gases.
- 6) Do not empty cylinders to a pressure below 25 psi (172 Kpa). The residual contents may become contaminated with air.
- 7) Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed. Do not purchase lecture bottles that cannot be returned.

4.7.4.9 Flammable Gases

Keep sources of ignition away from the cylinders.

- Oxidizers and flammable gases should be stored in areas separated by at least 20 feet or by a non-combustible wall.
- Bond and ground all cylinders, lines and equipment used with flammable compressed gases.

4.7.4.10 Highly Toxic Gases

Highly toxic gases, such as [arsine](#), [diborane](#), [fluorine](#), [hydrogen cyanide](#), [phosgene](#), and [silane](#), can pose a significant health risk in the event of a leak. Use of these materials requires written approval by the Principal Investigator and SUNUM facilities Management, using the *Particularly Hazardous Substances Use Approval* form.

The following additional precautions must be taken:

- 1) Use and store in a specially ventilated gas cabinet or fume hood.
- 2) Use coaxial (double walled) tubing with nitrogen between the walls for feed lines operating above atmospheric pressure.
- 3) Regulators should be equipped with an automatic shut-off to turn off gas supply in the event of sudden loss of pressure in the supply line.
- 4) An alarm system should be installed to check for leaks in routinely used gases with poor warning properties. The alarm level must be set at or lower than the permissible exposure limit of the substance.
- 5) Self-contained breathing apparatus (SCBA) may be appropriate for changing cylinders of highly toxic gases. Use of an SCBA requires enrollment in the [Respiratory Protection Program](#) and annual training and fit-testing.
- 6) Ensure storage and use areas are posted with [Designated Area](#) signage.

4.7.5 Cryogenic Safety

This section is to provide information and guidelines concerning the safe use of cryogenic fluids and to define the hazards associated with their use along with required safety precautions.

4.7.5.1 Definitions

A cryogenic liquid is defined as a liquid with a normal boiling point below -240°F (-150°C).

General

Cryogenic liquids will vent (boil off) from their storage containers as part of normal operation. As an example a 160-liter tank will vent the gas equivalent to 2 liters of liquid a day. Containers are typically of a vacuum jacketed design to minimize heat loss. Excessive venting and/or an isolated ice build-up on the vessel walls may indicate a fault in the vessel's integrity or a problem in the process line. A leaky container should be removed from service and taken to a safe, well-ventilated area immediately.

4.7.5.2 Precautions

There are a number of general precautions and safe practices that must be observed because of the extremely low temperatures and high rates of conversion into gas for all cryogenic liquids.

4.7.5.2.1 Extreme Cold Hazard

By definition, all cryogenic liquids are extremely cold. Cryogenic liquids and their vapors can rapidly freeze human tissue. Brief exposures that would not affect skin on the face or hands can damage delicate tissues such as the eyes. Prolonged exposure of the skin or contact with cold surfaces can cause frostbite. There is no initial pain but there is intense pain when frozen tissue thaws. Unprotected skin can stick to metal that is cooled by cryogenic liquids. The skin can then tear when pulled away. Even non-metallic materials are dangerous to touch at low temperature. Prolonged breathing of extremely cold air may damage the lungs.

Cryogenic liquids can cause many common materials such as carbon steel, rubber and plastics to become brittle or even break under stress.

4.7.5.2.2 Asphyxiation Hazard

Use and store cryogenic fluids in well ventilated areas only. All cryogenic liquids produce large volumes of gas when they vaporize. For example, one volume of liquid nitrogen vaporizes to 694 volumes of nitrogen gas at 20°C @ 1 atm. Air is normally 21% oxygen by volume. When this is reduced to 15-16% oxygen, symptoms of asphyxia (below) will develop. At 12% oxygen, the individual will lose consciousness without warning and may be unaware of any danger. When there is not enough oxygen, asphyxiation and death can occur very quickly. When cryogenic liquids form a gas, that gas is very cold and usually heavier than air. This cold, heavy gas does not disperse very well and can accumulate near the floor. Even if the gas is non-toxic, it displaces the air. Oxygen deficiency is a serious hazard in enclosed or confined spaces.

Signs of asphyxiation are giddiness, mental confusion, loss of judgment, loss of coordination, weakness, nausea, fainting and up to and including death. Only a few breaths of oxygen-depleted air are required to cause a rapid drop in dissolved oxygen in the blood. Mental failure and coma follow within seconds. Symptoms or warnings are generally absent, but even if present, the loss of mental abilities, coordination and weakness may make it impossible for victims to help themselves or summon help from others.

Most cryogenic liquids are odorless, colorless and tasteless when vaporized into the gaseous state. Most liquids have no color except liquid oxygen, which is light blue. However, extremely cold liquids and their vapors have a built-in warning property that appears whenever they are exposed to the atmosphere. The cold “boil-off” gases condense the moisture in the surrounding air, creating a highly visible fog. Fog clouds do not define the vapor cloud. They define the area where vapors are still cold enough to condense the moisture in the air. The vapor cloud may extend well beyond the fog cloud. Although fog clouds may be indicative of a release, they must never be used to define the leak area, which should not be entered by anyone.

Because cryogenic vapors are undetectable to the human sensory system, never enter a suspected oxygen-deficient area without an external source of breathing air or a monitor for the atmosphere to ensure that oxygen levels are safe.

4.7.5.2.3 Oxygen Enriched Air

Vaporization of liquid oxygen in an enclosed area can cause oxygen enrichment, which could saturate combustibles in the area such as workers’ clothing. This can cause a fire if an ignition source is present. Although oxygen is not flammable it will support and vigorously accelerate the combustion of other materials. Liquids at or below the boiling point of liquefied air can actually condense the surrounding air causing a localized oxygen-enriched atmosphere. Extremely cold cryogenics such Helium can even freeze or solidify the surrounding air.

4.7.5.2.4 Explosion Due to Rapid Expansion

Cryogenic liquids cannot be indefinitely maintained in the liquid state. If they are vaporized in sealed container they can produce enormous pressures that could rupture the container, for this reason pressurized cryogenic container are normally protected with multiple devices for over-pressure prevention. A pressure relief device must protect all selected equipment that may allow for the liquid to become trapped.

4.7.5.2.5 Special Helium Precautions

The most critical safety issue in dealing with liquid helium is its temperature. It is so cold that it will **FREEZE ALL GASES** except Helium. This includes not only H₂O, but also N₂ and O₂; all of these can freeze inside a liquid helium dewar or delivery lines, forming an "ice" plug which can potentially **CLOSE UP THE NECK AND CREATE A BOMB**. For this reason, it is imperative that procedures be in place followed exactly to prevent air or other gases from entering the liquid delivery lines at any time. Should a blockage be suspected remove the dewar to a safe location and contact the vender immediately. Attempting to transfer liquid helium in non-vacuum jacketed piping can cause air surrounding the outside of the transfer pipe to condense and liquefy. The nitrogen in this liquid will evaporate first, leaving an enriched oxygen liquid behind. The area where this liquid collects should be insulated and oxygen-compatible.

4.7.5.3 General Safety Practices

4.7.5.3.1 Storage and Use

All cryogenic liquids must be stored and used in a well-ventilated area.

1. Dewars: Non-pressurized, vacuum-walled containers which are equipped either with a loose-fitting cap or open top and are used for storage of small amounts of liquid.
2. Cryogenic Liquid Cylinders: These are sealed, vacuum-walled containers, which do contain pressure up to 350 psig. Cryogenic liquids can also be extracted from these containers.
3. Cryogenic Storage Tanks: These tanks range in size from 500 to 420,000 gallons and are always pad mounted. Liquid and gas can be extracted from these containers.

Personal safety

The eyes are the most sensitive body part to the extreme cold of the liquid and vapors. The recommended Personal Protective Equipment (PPE) for handling cryogens includes a full-face shield over safety glasses, loose-fitting thermal insulated or leather gloves, long sleeved shirts and trousers without cuffs. Gloves should be loose fitting to allow quick removal if liquid should be spilled inside. Gloves are not made to permit the hands to be immersed in a cryogenic liquid. They

will only provide short-term protection from accidental contact with the liquid. No metal jewelry rings watches etc... should be worn on hands or wrist while transferring cryogenic liquids.

4.7.5.3.2 Safety Practices

Cryogenic liquids must be handled, stored and used only in containers or systems designed in accordance with applicable standards, procedures or proven safe practices.

All systems components piping, valves etc...must be of the appropriate materials to withstand the extreme temperatures.

Pressure relief valves must be in place in systems and piping to prevent pressure build up.

Any system section that could be valved off while containing cryogenic liquid must have a pressure relief valve. Pressure relief valve relief ports must be positioned to face toward a safe location.

Transfer operations involving open cryogenic containers, such as dewars must be done slowly, while wearing all required PPE. Care must be used not to contact non-insulated pipes and system components.

Open transfers will be allowed only in well-ventilated areas.

Do not use a funnel while transferring cryogenic liquids.

Use tongs or other similar devices to immerse and remove objects from cryogenic liquids.

Hazard reviews are required on all newly purchased, built or modified tools using cryogenic materials. Contact Lab Supervisors to start the process.

4.7.5.3.3 Transferring cryogenics:

When transferring liquid nitrogen or helium, the following steps should be observed to avoid accidents:

- Gloves, eye protection, and closed shoes must be worn.
- Doors should be propped open to increase ventilation.
- Tanks on wheels must be chocked or held by another person.
- The transfer must be continuously attended and helium transfers MUST be done in buddy pairs.

Since the possibility of a helium quench is higher when filling the magnet, and since the transfer involves manual operations, there is a remote possibility that an operator could be rendered unconscious at the time of a quench. Fills must only be done by two operators particularly if a Helium fill is being carried out.

4.7.5.4 Approvals

Approval is required prior to purchase of any flammable or toxic cryogenic fluid.

TABLE I- Properties of Cryogenic Fluids. Table 6

Gas	Boiling Point (0C)	Boiling Point (0K)	Volume Expansion to Gas
Helium-3	-269.9	3.2	757 to 1
Helium-4	-268.9	4.2	757 to 1
Hydrogen	-252.7	20.4	851 to 1
Deuterium	-249.5	23.6	...
Tritium	-248.0	25.1	...
Neon	-245.9	27.2	1438 to 1
Nitrogen	-195.8	77.3	696 to 1
Carbon monoxide	-192.0	81.1	...
Fluorine	-187.0	86.0	888 to 1
Argon	-185.7	87.4	847 to 1
Oxygen	-183.0	90.1	860 to 1
Methane	-161.4	111.7	578 to 1
Krypton	-151.8	121.3	700 to 1
Tetrafluoromethane	-128	145	...
Ozone	-111.9	161.3	...
Xenon	-109.1	164.0	573 to 1
Ethylene	-103.8	169.3	...
Boron trifluoride	-100.3	172.7	...
Nitrous oxide	-89.5	183.6	666 to 1
Ethane	-88.3	184.8	...
Hydrogen chloride	-85.0	188.0	...
Acetylene	-84.0	189.1	...
Fluoroform	-84.0	189.1	...
1,1-Difluoroethylene	-83.0	190.0	...
Chlorotrifluoromethane	-81.4	191.6	...
Carbon dioxide	-78 5(b)	194.6	553 to 1

Table 6 Properties of Cryogenic Fluids

4.7.5.5 Emergency Procedures

Remember, oxygen-deficient atmospheres are an invisible danger. They have no warning properties.

Never enter an area suspected of being oxygen-deprived without a source of supplied air. Use monitoring devices to ensure oxygen levels are adequate.

When it is necessary to work in an oxygen-deficient area, supplied air must be provided.

Should a Dewar of cryogenic liquid be venting continuously call the supplying vender immediately.

4.7.5.6 First Aid

4.7.5.6.1 Frostbite

For skin contact, remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts: tissue damage may result. As soon as practical, place the affected area in a warm water bath which has a temperature that does not exceed 105°F. Never use dry heat. Call a physician as soon as possible. Frozen tissue is usually pain-free and appears waxy with a possible yellow color. It will become swollen, painful and prone to infection when thawed. If the frozen part of the body has been thawed, cover the area with a dry sterile dressing pending medical care. In case of massive exposure, remove the victims' clothing while showering him or her with warm water. Call a physician immediately. If the eyes are exposed to the extreme cold of the liquid or vapors, immediately warm the frostbite area with warm water not exceeding 105°F and seek medical attention. If the body temperature is depressed, the person must be warmed gradually. Shock may occur during the correction of hypothermia. Cardiac dysrhythmia may be associated with severe hypothermia.

4.7.5.6.2 Asphyxiation

Anyone suffering from a lack of oxygen should be quickly moved to an area with a normal atmosphere. If the victim is not breathing, artificial respiration should be administered immediately. Give supplemental oxygen with respiration if oxygen is available.

4.7.5.7 Training

Training will be provided by university personnel monthly or as needed.

4.7.5.8 Additional Information:

General information on Cryogenic fluids

<http://www.airproducts.com/nr/rdonlyres/c50df690-bd10-4348-a986-bf8a6e12ed2f/0/safetygram16.pdf>

<http://www.ccohs.ca/oshanswers/chemicals/cryogenic/cryogen1.html>

Oxygen deficient

<http://www.airproducts.com/nr/rdonlyres/35b1bc31-7c0e-455b-a723-8255ff28ddba/0/safetygram17.pdf>

Cryogenic Liquid Containers

<http://www.airproducts.com/nr/rdonlyres/38000ecf-e07b-4288-8ff9-73699c70c882/0/safetygram27.pdf>

Liquid Helium

<http://www.airproducts.com/nr/rdonlyres/f655730b-dfee-4eb0-a6c5-fac10d5ae480/0/safetygram22.pdf>

Liquid H₂

<http://www.airproducts.com/nr/rdonlyres/780e8a00-f1bf-435c-8219-6601da6632f0/0/safetygram09.pdf>

5 BIOLOGICAL SAFETY

5.1 PRINCIPLES OF BIOSAFETY

5.1.1 Risk Groups

Infectious agents may be classified into risk groups based on their relative hazard. The table below, which was excerpted from the NIH Recombinant DNA Guidelines, presents the "Basis for the Classification of Biohazardous Agents by Risk Group." Table 7

Risk Group 1 (RG1)	Agents that are not associated with disease in healthy adult humans
Risk Group 2 (RG2)	Agents that are associated with human disease which is rarely serious and for which preventive or therapeutic interventions are <i>often</i> available
Risk Group 3 (RG3)	Agents that are associated with serious or lethal human disease for which preventive or therapeutic interventions <i>may be</i> available (high individual risk but low community risk)
Risk Group 4 (RG4)	Agents that are likely to cause serious or lethal human disease for which preventive or therapeutic interventions are <i>not usually</i> available (high individual risk and high community risk) Work with Risk Group 4 agents IS PROHIBITED at Sabanci University.

Table 7 Basis for the Classification of Biohazardous Agents by Risk Group

Laboratories and animal facilities are classified according to their design features, construction and containment capabilities. Combinations of these design characteristics represent levels of containment appropriate for work with agents in various risk groups. Containment appropriate for given work is the biosafety level respectively that provides appropriate containment for the various risk group agents. Biosafety Levels are discussed in greater detail below.

5.1.2 Containment

The term "containment" is used in describing safe methods for managing infectious agents in the laboratory environment where they are being handled or maintained. The purpose of containment is to reduce or eliminate exposure of laboratory workers, other people and the outside environment to potentially hazardous agents. The three elements of containment include laboratory practice and technique, safety equipment, and facility design.

Primary containment -- the protection of personnel and the immediate laboratory environment from exposure to infectious agents, is provided by good microbiological technique and the use of appropriate safety equipment. The use of vaccines may provide an increased level of personal protection.

Secondary containment -- the protection of the environment external to the laboratory from exposure to infectious materials, is provided by a combination of facility design and operational practices. The risk assessment of the work to be done with a specific agent will determine the appropriate combination of work practices, safety equipment and facility design to provide adequate containment.

Laboratory Practice and Technique -- The most important element of containment is strict adherence to standard microbiological practices and techniques. Persons working with infectious agents or infected materials must be aware of potential hazards, and must be trained and proficient in the practices and techniques required for handling such material safely. The PI or laboratory supervisor is responsible for providing or arranging for appropriate training of personnel.

Each laboratory should develop an operational manual which identifies specific hazards that will or may be encountered, and which specifies practices and procedures designed to minimize or eliminate risks. Personnel should be advised of special hazards and should be required to read and to follow the required practices and procedures. A scientist trained and knowledgeable in appropriate laboratory techniques, safety procedures and hazards associated with the handling of infectious agents must direct laboratory activities.

When standard laboratory practices are not sufficient to control the hazard associated with a particular agent or laboratory procedure, additional measures may be needed. The PI is responsible for selecting additional safety practices, which must be in keeping with the hazard associated with the agent or procedure.

Laboratory personnel, safety practices and techniques must be supplemented by appropriate facility design and engineering features, safety equipment and management practices.

Safety Equipment (Primary Barriers) -- Safety equipment includes biological safety cabinets, enclosed containers (i.e., safety centrifuge cups) and other engineering controls designed to remove or minimize exposures to hazardous biological materials. The biological safety cabinet (BSC) is the principal device used to provide containment of infectious splashes or aerosols generated by many

microbiological procedures. More information on BSC's may be found at the EHRS website and CDC website.

Safety equipment also may include items for personal protection such as personal protective clothing, respirators, face shields, safety glasses or goggles. Personal protective equipment is often used in combination with other safety equipment when working with biohazardous materials. In some situations, personal protective clothing may form the primary barrier between personnel and the infectious materials.

Facility Design (Secondary Barriers) -- The design of a facility is important in providing a barrier to protect people working inside and outside the laboratory, and to protect people or animals in the community from infectious agents which may be accidentally released from the laboratory. Facilities must be commensurate with the laboratory's function and the recommended biosafety level for the agent being manipulated.

The recommended secondary barrier(s) will depend on the risk of transmission of specific agents. For example, the exposure risks for most laboratory work in Biosafety Level 1 and 2 facilities will be direct contact with the agents, or inadvertent contact exposures through contaminated work environments. Secondary barriers in these laboratories may include separation of the laboratory work area from public access, availability of a decontamination facility (e.g., autoclave) and hand washing facilities.

As the risk for aerosol transmission increases, higher levels of primary containment and multiple secondary barriers may become necessary to prevent infectious agents from escaping into the environment. Such design features could include specialized ventilation systems to assure directional airflow, air treatment systems to decontaminate or remove agents from exhaust air, controlled access zones, airlocks at laboratory entrances, or separate buildings or modules for isolation of the laboratory.

5.1.3 Biological Safety Levels

A biosafety level is the level of the bio-containment precautions required to isolate dangerous [biological agents](#) in an enclosed facility. The levels of containment range from the lowest biosafety level 1 to the highest at level 4. In the United States, the Centers for Disease Control and Prevention (CDC) have specified these levels. In the European Union, the same biosafety levels are defined in a [directive](#) ²².

The term "containment" is used in describing safe methods for managing infectious materials in the laboratory environment where they are being handled or maintained. The purpose of containment is to reduce or eliminate exposure of laboratory workers, other persons, and the outside environment to potentially hazardous agents.²³

Bio-containment can be classified by the relative danger to the surrounding environment as biological safety levels (BSL). As of 2006, there are four safety levels. These are called *BSL1* through *BSL4*. SUNUM labs confine only up to BSL2 specifications in general.

5.1.3.1 Biosafety Level 1

This level is suitable for work involving well-characterized agents not known to consistently cause disease in healthy adult humans, and of minimal potential hazard to laboratory personnel and the environment (CDC,1997) It includes several kinds of bacteria and viruses including canine hepatitis, Escherichia coli, varicella (chicken pox), as well as some cell cultures and non-infectious bacteria. At this level precautions against the biohazardous materials in question are minimal, most likely involving gloves and some sort of facial protection. The laboratory is not necessarily separated from the general traffic patterns in the building. Work is generally conducted on open bench tops using standard microbiological practices. Usually, contaminated materials are left in open (but separately indicated) rubbish receptacles. Decontamination procedures for this level are similar in most respects to modern precautions against everyday microorganisms (i.e., washing one's hands with anti-bacterial soap, washing all exposed surfaces of the lab with disinfectants, etc.). In a lab environment all materials used for cell and/or bacteria cultures are decontaminated via autoclave. Laboratory personnel have specific training in the procedures conducted in the

²² http://en.wikipedia.org/wiki/Biosafety_level

²³ <http://www.asu.edu/uagc/EHS/documents/biosafetymanual.pdf>

laboratory and are supervised by a scientist with general training in microbiology or a related science.

5.1.3.2 Biosafety Level 2

This level is similar to Biosafety Level 1 and is suitable for work involving agents of moderate potential hazard to personnel and the environment. It includes various bacteria and viruses that cause only mild disease to humans, or are difficult to contract via aerosol in a lab setting, such as *C.difficile*, hepatitis A, B, and C, influenza A, Lyme disease, dengue fever, *Salmonella*, mumps, *Bacillus subtilis*, measles, HIV, scrapie, MRSA, VRSA, etc. Genetically modified organisms have also been classified as level 2 organisms, even if they pose no direct threat to humans. This designation is used to limit the release of modified organisms into the environment. Approval by the FDA is required to release these organisms. An example is genetically modified food crops. BSL-2 differs from BSL-1 in that:

1. Laboratory personnel have specific training in handling pathogenic agents and are directed by scientists with advanced training;
2. Access to the laboratory is limited when work is being conducted;
3. Extreme precautions are taken with contaminated sharp items
4. Certain procedures in which infectious aerosols or splashes may be created are conducted in biological safety cabinets or other physical containment equipment.

5.1.3.3 Biosafety Level 3

Risk Group 3 infectious agents are pathogens that usually cause serious human or animal disease, or which can result in serious economic consequences, but do not ordinarily spread by casual contact from one individual to another (high individual risk, low community risk), or that can be treated by antimicrobial or antiparasitic agents.

Risk Group 3 pathogens include bacteria such as anthrax, Q Fever, tuberculosis, and viruses such as hanta viruses, Human immunodeficiency viruses (HIV - all isolates), eastern and western equine encephalitis viruses.

Facilities, equipment and procedures required to contain risk group 3 organisms include:

Specialized design and construction of laboratories, with controlled access double door entry and body shower. All wall penetrations must be sealed. Ventilation system design must ensure that air pressure is negative to surrounding areas at all times, with no recirculation of air; air exhausted

through a dedicated exhaust or HEPA filtration system. Minimum furnishings, all readily cleanable and sterilizable (fumigation). Laboratory windows sealed and unbreakable. Backup power available.

Equipment must include an autoclave, certified HEPA filtered class II biological safety cabinet for organism manipulations, and a dedicated handwashing sink with foot, knee or automatic controls, located near the exit. Personal protective equipment should include solid front laboratory clothing worn only in the laboratory, head covers and dedicated footwear, gloves worn when handling infected animals and appropriate respiratory protection, depending on the infectious agents in use.

Exit procedures should include showers, depending on infectious agents used and manipulations involved. All animal wastes to be disposed of as contaminated laboratory materials. All activities involving infectious materials to be conducted in biological safety cabinets or other appropriate combinations of personal protective and physical containment devices.

Laboratory staff must be fully trained in the handling of pathogenic and other hazardous material, in the use of safety equipment, disposal techniques, handling of contaminated waste, and emergency response. Standard Operating Procedures must be provided and posted within the laboratory outlining operational protocols, waste disposal, disinfection procedures and emergency response. The facility must have a medical surveillance program appropriate to the agents used, which includes serum storage for all personnel working in the containment laboratory and an accident report system.

5.1.3.4 Biosafety Level 4

Risk Group 4 infectious agents are pathogens that usually produce very serious human or animal disease, often untreatable, and may be readily transmitted from one individual to another, or from animal to human or vice-versa directly or indirectly, or by casual contact (high individual risk, high community risk).

Risk Group 4 infectious agents are all viruses, such as, Ebola viruses, Herpes B virus (Monkey virus), Foot and Mouth Disease.

Containment Level 4 is the highest level of containment and represents an isolated unit that is completely self-contained to function independently. Facilities are highly specialized, secure with

an air lock for entry and exit, Class III biological safety cabinets or positive pressure ventilated suits, and a separate ventilation system with full controls to contain contamination.

Only fully trained and authorised personnel may enter the Level 4 containment laboratory. On exit from the area, personnel will shower and re-dress in street clothing. All manipulations with agents must be performed in Class III biological safety cabinets or in conjunction with one-piece, positive-pressure-ventilated suits.

The following table summarizes the biosafety levels. Table 8 ²⁴

Biosafety Level	1	2
Infectious Agents	unlikely to cause disease in healthy workers or animals low individual and community risk	can cause human or animal disease but unlikely to be a serious hazard moderate individual risk, limited community risk effective treatments available
Examples of infectious agents in this risk level		E. coli, California encephalitis viruses, many influenza viruses
Facilities	standard well-designed experimental animal and laboratory facilities	Level 1 plus: Separate laboratory, room surfaces impervious and readily cleaned, biohazard sign
Safety Equipment	hand washing facilities, laboratory coats	Level 1 plus: autoclave, HEPA filtered class I or II biological safety cabinet, personal protective equipment

²⁴ http://www.ccac.ca/en/CCAC_Programs/ETCC/Module04/15.html

Procedures	basic safe laboratory practices	use of personal protective equipment laboratory coat worn only in the laboratory, gloves, decontamination
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Table 8 Biosafety Levels

5.1.4 Biological Safety- The Basics

- Work surfaces should be decontaminated at the end of the each day and after spill of viable material.
- All contaminated liquid or solid wastes must be decontaminated before disposal.
- Mouth pipetting is prohibited- a bulb or pipettor must be used.
- As with any laboratory, eating, drinking, application of cosmetics, taking of medicines etc. are not permitted in the work area. Food for consumption should not be stored in laboratory fridges or taken into the laboratory.
- All procedures must be performed so as to minimise the creation of aerosols.
- Laboratory coats or gowns should be worn over street clothes whilst working in the lab. These should not be worn away from the lab work area.
- Always consider the safety of cleaners and technicians- never leave hazardous materials in regular lab bins, or in glassware which has been left for washing.
- All equipment from Containment Level 2 laboratories, including laptops and desktop computers should be wiped down with a suitable disinfectant before they are removed from the laboratory or referred to staff for maintenance.
- Never dispose of chemicals by throwing them into wastebaskets, bins or dustbins. Never put chemicals down any sink or drain unless you are SURE this is an acceptable disposal route for the chemical in question.
- Never mix chemicals together unless you are sure that they are compatible.
- Following can be disposed of to the foul drainage system with copious amounts of water:
 1. Aqueous solutions containing less than 0.01% organic solvents (excluding chlorinated solvents).
 2. Dilute acid, alkali or ammonia solutions (less than 10 % v/v).
 3. Harmless soluble inorganic salts (including all drying agents such as CaCl₂, MgSO₄, Na₂SO₄, P₂O₅).
 4. Hypochlorite solutions from destroying cyanides, phosphines, etc.
 5. Please note that chemical substances should never be discharged into surface water drains (that is, drains in the road or ground outside).

6. Solid and liquid waste chemicals should be decanted into a clean secure container of a suitable material. Suitable materials are as follows:

- Glass bottles can be used for most chemicals EXCEPT hydrofluoric acid waste.
- Plastic bottles are suitable for acids and alkalis but never put aggressive solvents such as dichloromethane into plastic containers unless the container is made of HDPE.
- Lidded plastic buckets can be used for solid waste. Please make sure that the lid fits tightly.
- Steel drums are suitable for large quantities of organic solvents, neutral aqueous solutions and oils but are not suitable for acids and alkaline.
- The containers must be properly labelled with the following information:

-Name of the user-

-The date

-The name of the waste substance or substances in the container

-Any appropriate hazard label or warning

5.1.5 Material Safety Data Sheets (MSDS) for Infectious Substances

Material Safety Data Sheets (MSDS), regulated under Workplace Hazardous Materials Information System (WHMIS) legislation, for chemical products have been available to workers for many years. However because many laboratory workers, whether in research, public health, teaching, etc., are exposed to not only chemicals but infectious substances as well, there was a large gap in the readily available safety literature for Students, faculty and lab associatess. These MSDS are produced for personnel working in the life sciences as quick safety reference material relating to infectious micro-organisms.

The MSDS are organized to contain health hazard information such as infectious dose, viability (including decontamination), medical information, laboratory hazard, recommended precautions, handling information and spill procedures. The intent of these documents is to provide a safety resource for laboratory personnel working with these infectious substances. Because these workers are usually working in a scientific setting and are potentially exposed to much higher concentrations of these human pathogens than the general public, the terminology in these MSDS is technical and detailed, containing information that is relevant specifically to the laboratory setting. It is hoped along with good laboratory practices, these MSDS will help provide a safer, healthier environment for everyone working with infectious substances.

Please see the below link for further detailed information:²⁵

5.2 STANDARD OPERATING PROCEDURES FOR WORKING WITH BIOHAZARDOUS MATERIALS

5.2.1 Pipettes and Pipetting Aids

Pipettes are used for volumetric measurements and transfer of fluids that may contain Infectious, toxic, corrosive or radioactive agents. Laboratory-associated infections have occurred from oral aspiration of infectious materials, mouth transfer via a contaminated finger and inhalation of aerosols. Exposure to aerosols may occur when liquid from a pipette is dropped onto the work surface, when cultures are mixed by pipetting, or when the last drop of an inoculum is blown out. A pipette may become a hazardous piece of equipment if improperly used. The safe pipetting techniques that follow are required to minimize the potential for exposure to biologically hazardous materials:

- Never mouth pipette. Always use a pipetting aid.
- If working with biohazardous or toxic fluid, confine pipetting operations to a biological safety cabinet.
- Always use cotton-plugged pipettes when pipetting biohazardous or toxic materials, even when safety pipetting aids are used.
- Do not prepare biohazardous materials by bubbling expiratory air through a liquid with a pipette.
- Do not forcibly expel biohazardous material out of a pipette.
- Never mix biohazardous or toxic material by suction and expulsion through a pipette.
- When pipetting, avoid accidental release of infectious droplets. Place a disinfectant soaked towel on the work surface and autoclave the towel after use.
- Use "to deliver" pipettes rather than those requiring "blowout".
- Do not discharge material from a pipette at a height. Whenever possible allow the discharge to run down the container wall.
- Place contaminated, reusable pipettes horizontally in a pan containing enough liquid disinfectant to completely cover them. Do not place pipettes vertically into a cylinder. Autoclave the pan and pipettes as a unit before processing them as dirty glassware for reuse (see section D, Decontamination).

²⁵ <http://www.phac-aspc.gc.ca/msds-ftss/index-eng.php>

- Discard contaminated disposable pipettes in an appropriate sharps container. Autoclave the container when it is 2/3 to 3/4 full and dispose of as infectious waste. Place pans or sharps containers for contaminated pipettes inside the biological safety cabinet to minimize movement in and out of the BSC.

5.2.2 Syringes and Needles

Syringes and hypodermic needles are dangerous instruments. *The use of needles and syringes should be restricted to procedures for which there is no alternative.* Blunt cannulas should be used as alternatives to needles wherever possible (i.e., procedures such as oral or intranasal animal inoculations). Needles and syringes should never be used as a substitute for pipettes. When needles and syringes must be used, the following procedures are recommended:

- Use disposable safety-engineered needle-locking syringe units whenever possible.
- When using syringes and needles with biohazardous or potentially infectious agents, work in a biological safety cabinet whenever possible.
- Wear gloves.
- Fill the syringe carefully to minimize air bubbles.
- Expel air, liquid and bubbles from the syringe vertically into a cotton pledget moistened with disinfectant.
- Do not use a syringe to mix infectious fluid forcefully.
- Do not contaminate the needle hub when filling the syringe in order to avoid transfer of infectious material to fingers.
- Wrap the needle and stopper in a cotton pledget moistened with disinfectant when removing a needle from a rubber-stoppered bottle.
- Bending, recapping, clipping or removal of needles from syringes is prohibited. If you must recap or remove a contaminated needle from a syringe, use a mechanical device (e.g. forceps) or the one-handed scoop method. The use of needle-nipping devices is prohibited (needle-nipping devices must be discarded as infectious waste).
- Use a separate pan of disinfectant for reusable syringes and needles. Do not place them in pans containing pipettes or other glassware in order to eliminate sorting later.
- Used disposable needles and syringes must be placed in appropriate sharps disposal containers and discarded as infectious waste.

The Occupational Safety and Health Administration (OSHA) revised the Occupational Exposure to Bloodborne Pathogens Standard (29 CFR Part 1910.1030) in 2001 to include new efforts to help

reduce needlestick injuries among healthcare workers and others who handle medical sharps. OSHA now requires the University to involve non-managerial employees in selecting safer medical sharps devices.

5.2.3 Safe and Effective Use of Biological Safety Cabinets

In general:

Make sure your BSC is certified prior to use, when it is installed or after it is moved, and annually thereafter. (For information on cabinet certification contact EHRS by phone (215-898-4453) or email.

- Understand how your cabinet works. The NIH / CDC document, [Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets](#), provides thorough information. Also consult the manufacturer's operational manual.
- Monitor alarms, pressure gauges or flow indicators for any major fluctuation or changes possibly indicating a problem with the unit. Immediately notify LAB SUPERVISORS of cabinets that are not operating properly. DO NOT attempt to adjust the speed control or alarm settings.
- Do not disrupt the protective airflow pattern of the BSC. Make sure lab doors are closed before starting work in the BSC.
- Plan your work and proceed conscientiously.
- Minimize the storage of materials in and around the BSC.
- Hard ducted (Type B2, Total Exhaust) cabinets should be left running at all times.
- Cabinets that are not vented to the outside may be turned off when not in use, however, be sure to allow the BSC to run for at least 10 minutes before starting work.

Operational directions:

- Limit traffic in the area when the cabinet is in use.
- If there is an UV light incorporated within the cabinet, do not leave it on while working in the cabinet or when occupants are in the laboratory.
- Before using, wipe work surface with 70% alcohol. Wipe off each item you need for your procedures and place in cabinet.
- DO NOT place objects over the front air intake grille. Keep all materials at least 4 inches inside the sash. DO NOT place items on top of the unit or block the rear exhaust grille.

- Segregate contaminated and clean items. Work from "clean to dirty."
- Place a pan with disinfectant and/or a sharps container inside the BSC for pipette discards. DO NOT use vertical pipette discard canisters on the floor outside cabinet.
- It is not necessary to flame items. This creates turbulence in airflow and may compromise sterility; heat build-up may damage the filters.
- Move arms slowly when removing or introducing new items into the BSC.
- If you use a piece of equipment that creates air turbulence in the BSC (such as a centrifuge, blender) place equipment in the back 1/3 of the cabinet; stop other work while equipment is operating.
- Protect the building vacuum system from biohazards by placing an in-line HEPA cartridge filter between the vacuum trap system and the source valve in the cabinet.
- Clean up all spills in the cabinet immediately. Allow cabinet to run for 10 minutes before resuming work.
- When work is completed-remove all materials and wipe all interior surfaces with 70% alcohol.
- Remove lab coat and wash hands thoroughly before leaving laboratory.

5.2.4 Cryostats

Frozen sections of unfixed human tissue or animal tissue infected with an etiologic agent pose a risk because accidents can occur. Freezing tissue does not necessarily inactivate infectious agents. Freezing propellants under pressure should not be used for frozen sections as they may cause spattering of droplets of infectious material. Gloves should be worn during preparation of frozen sections. When working with biohazardous material in a cryostat, the following is recommended:

- Consider the contents of the cryostat to be contaminated and decontaminate it frequently with 70% ethanol.
- Consider trimmings and sections of tissue that accumulate in the cryostat to be potentially infectious and remove them during decontamination.
- Defrost and decontaminate the cryostat with a tuberculocidal hospital disinfectant once a week and immediately after tissue known to contain bloodborne pathogens, *M. tuberculosis* or other infectious agents is cut.
- Handle microtome knives with extreme care. Stainless steel mesh gloves should be worn when changing knife blades.
- Consider solutions used for staining potentially infected frozen tissue sections to be contaminated.

5.2.5 Centrifuge Equipment

Hazards associated with centrifuging include mechanical failure and the creation of aerosols. To minimize the risk of mechanical failure, centrifuges must be maintained and used according to the manufacturer's instructions. Users should be properly trained and operating instructions that include safety precautions should be prominently posted on the unit.

Aerosols are created by practices such as filling centrifuge tubes, removing plugs or caps from tubes after centrifugation, removing supernatant, and resuspending sedimented pellets. The greatest aerosol hazard is created if a tube breaks during centrifugation. To minimize the generation of aerosols when centrifuging biohazardous material, follow the procedures below:

- Use sealed tubes and safety buckets that seal with O-rings. Before use, inspect tubes, O-rings and buckets for cracks, chips, erosions, bits of broken glass, etc. Do not use aluminum foil to cap centrifuge tubes because it may detach or rupture during centrifugation.
- Fill and open centrifuge tubes, rotors and accessories in a BSC. Avoid overfilling of centrifuge tubes so that closures do not become wet. After tubes are filled and sealed, wipe them down with disinfectant.
- Add disinfectant to the space between the tube and the bucket to disinfect material in the event of breakage during centrifugation.
- Always balance buckets, tubes and rotors properly before centrifugation.
- Do not decant or pour off supernatant. Use a vacuum system with appropriate in-line reservoirs and filters.
- Work in a BSC when re-suspending sedimented material. Use a swirling rotary motion rather than shaking. If shaking is necessary, wait a few minutes to permit the aerosol to settle before opening the tube.

Small low-speed centrifuges may be placed in a BSC during use to contain aerosols. High speed centrifuges pose additional hazards. Take precautions to filter the exhaust air from vacuum lines; avoid metal fatigue resulting in disintegration of rotors; and use proper cleaning techniques and centrifuge components. Follow manufacturers' recommendations meticulously to avoid metal fatigue, distortion and corrosion.

Avoid the use of celluloid (cellulose nitrate) tubes with biohazardous materials. Celluloid centrifuge tubes are highly flammable and prone to shrinkage with age. They distort on boiling and can be highly explosive in an autoclave. If celluloid tubes must be used, an appropriate chemical disinfectant must be used to decontaminate them.

5.2.6 Aerosol Producing Devices

The use of devices such as *ultrasonic disrupters, grinders and homogenizers* to disrupt biohazardous materials results in considerable aerosol production and should be performed in a BSC whenever possible. Special care and barrier protection (splash shields, goggles, bench napkins, gloves, etc.) are important not only during the agitation/disruption process but also when handling the finished product. Allow your vessel to sit for a short time to allow your product to settle before opening. Review the operations manual for the device you are using, paying special attention to those areas of the device that are susceptible to contamination by your product and decontaminate appropriately after use, especially when working with potentially infectious materials.

Sound at ultrasonic frequencies can damage hearing.

When purchasing ultrasonic equipment purchase shielded or quiet machines.

Make sure that ultrasonic equipment is sited in infrequently used areas.

Fix items such as probes securely to minimise the sound.

Wear ear protectors if staying in the room with the ultrasonic equipment. Make sure that others around you are not exposed.

Safety blenders are designed to prevent leakage from the bottom of the blender jar, provide a cooling jacket to avoid biological inactivation and to withstand sterilization by autoclaving. If blender rotors are not leak proof, test them with sterile saline or dye solution prior to use with biohazardous material. The use of glass blender jars is not recommended because of the breakage potential. If they must be used, cover the glass jar with a polypropylene jar to prevent spraying of glass and contents in the event it breaks. Use safety blenders in a BSC to prevent the accidental release of aerosol during the blending process. During use, place a towel moistened with disinfectant over the top of the blender. Before opening the blender jar, allow the unit to rest for at least one minute to allow the aerosol to settle. Decontaminate the device promptly after use.

Lyophilizers may be used to freeze-dry biohazardous material. Depending on each lyophilizer design, infectious aerosol production may occur when biohazardous material is loaded or removed from the lyophilizer unit. If possible, load sample material in a BSC. Be sure the vacuum pump exhaust is HEPA-filtered to remove any hazardous agents or, alternatively, vent the pump into a BSC. After lyophilization is completed, disinfect all surfaces of the unit that have been exposed to the agent. If the lyophilizer is equipped with a removable chamber, close it off and move it to a BSC for unloading and decontamination. Handle cultures as infrequently as possible and use vapor traps wherever possible.

Open all glass *ampoules* containing liquid or lyophilized culture material in a BSC to contain the aerosol produced. Gloves must be worn. To open, nick the neck of the ampoule with a file, wrap it in disinfectant soaked towel, hold the ampoule upright and snap it open at the nick. Reconstitute the contents of the ampoule by slowly adding liquid to avoid aerosolization of the dried material. Mix the contents without bubbling and withdraw it into a fresh container. Discard the towel and ampoule top and bottom as infectious waste.

5.2.7 Loop Sterilizers and Bunsen Burners

Sterilization of inoculating loops or needles in an open flame generates small-particle aerosols that may contain viable microorganisms. The use of a shielded electric incinerator minimizes aerosol production during loop sterilization. Alternatively, disposable plastic loops and needles may be used for culture work where electric incinerators or gas flames are not available. The loops are semi-quantitative and can be used for counting bacteria.

The use of gas burners in BSCs is not recommended. These burners can produce turbulence that disturbs the protective airflow patterns of the cabinet. In many biosafety cabinets, a portion of the total air volume is recirculated in the work area allowing flammable vapors or gases to accumulate thereby creating a fire hazard. Additionally, the heat produced by the continuous flame may damage the HEPA filter.

If a gas burner must be used, select a touch-plate burner with a pilot light. In addition, appropriate hard piping from the house gas line must be used and an easily accessible emergency shut-off valve (specifically identified as such) must be placed on the outside of the biosafety cabinet.

5.2.8 Housekeeping

Good housekeeping in laboratories is essential to reduce risks and protect the integrity of biological experiments. Routine housekeeping must be relied upon to provide work areas free of significant sources of contamination. Housekeeping procedures should be based on the highest degree of risk to which personnel and experimental integrity may be subjected.

Laboratory personnel are responsible to clean laboratory benches, equipment and areas that require specialized technical knowledge. Laboratory staff is responsible to:

- Secure biohazardous materials at the conclusion of work.
- Keep the laboratory neat and free of clutter - surfaces should be clean and free of infrequently used chemicals, biologicals, glassware and equipment. Access to sinks, eyewashes, emergency showers and fire extinguishers must not be blocked.
- Decontaminate and discard infectious waste – do not allow it to accumulate in the laboratory.
- Dispose of old and unused chemicals promptly and properly. To have your waste chemicals removed, ‘INQUIRE from CALL CENTER’.
- Provide a workplace that is free of physical hazards - aisles and corridors should be free of tripping hazards. Attention should be paid to electrical safety, especially as it relates to the use of extension cords, proper grounding of equipment, and avoidance of overloaded electrical circuits and avoidance of the creation of electrical hazards in wet areas.
- Remove unnecessary items on floors, under benches or in corners.
- Properly secure all compressed gas cylinders.
- Never use fume hoods or biosafety cabinets for storage.

Practical custodial concerns include:

- Dry sweeping and dusting that may lead to the formation of aerosols is not permitted.
- The use of a wet or dry industrial type vacuum cleaner is prohibited to protect personnel as well as the integrity of the experiment. They are potent aerosol generators and, unless equipped with high efficiency particulate air (HEPA) filters, must not be used in the biological research laboratory. Wet and dry units with HEPA filters on the exhaust are available from a number of manufacturers.

5.2.9 Transportation and Shipment of Biological Materials

The transportation and shipment of biological materials is subjected to strict regulatory controls. Individuals involved in the transportation and shipment of infectious substances must receive training on the applicable regulations and requirements before shipping such materials. Biological materials transported by laboratory personnel within a laboratory or between buildings must be contained in such a way as to prevent release to the environment in case of an accident by following the procedure below:

<http://www.drs.illinois.edu/bss/programareas/transport/index.aspx#intracampus>

Biological samples must be placed in a primary container or vessel that is a securely closed, leak-proof (or o-ring) tube, vial or ampoule, which is then placed in an unbreakable, lidded, watertight, secondary container.

If the outside of the primary container or vessel is suspected of being contaminated, decontaminate prior to placing in secondary container using 10% bleach solution, an EPA approved disinfectant, or a disinfectant appropriate for the biological material in use.

All biohazards must be labeled with the international biohazard symbol on the outside of the secondary container.

When transporting liquids in glass vials/containers, place enough absorbent material, such as paper towels, in the space at the top, bottom, and sides between the primary and secondary containers to absorb the entire contents of the primary container(s) in case of breakage or leakage.

The outside of the secondary container must be free of any biohazardous material so that the package can be carried safely between buildings without wearing gloves or lab coats outside. The package must be taken directly to its intended location.

If a spill occurs during transport, do not attempt to clean it up without appropriate spill response material and Personal Protective Equipment (PPE). Keep other persons clear of the spill.

5.2.9.1 Packaging Unregulated Biological Materials

All biological materials must be packaged according to a triple packaging system. The three components of a triple packaging system are:

- Primary receptacle
- Leak-proof secondary container

- Rigid outer container

The primary receptacle holds the biological material and must be leak-proof, watertight. It is packed in the secondary container in such a way that, under normal conditions of transport, they will not break, be punctured, or leak their contents into the secondary container. If the primary receptacle is fragile, it must be individually wrapped or separated to prevent contact between multiple primary receptacles.

The secondary container is a durable, watertight, leak-proof container that encloses and protects the primary receptacle(s). Several cushioned primary receptacles may be placed in one secondary container. If the primary receptacle contains any liquid, the secondary container must contain enough absorbent material to absorb all of the fluid from the primary receptacle(s) in case of breakage.

The outer container is a rigid and durable container with one side that is at least 10 cm x 10 cm (or 4 inches by 4 inches) that houses the secondary container. The outer package should be properly marked and labeled. It should be able to withstand outside influences such as physical damage while in transit. An itemized list of package contents must be included between the outer and secondary container.

(<http://www.drs.illinois.edu/bss/factsheets/TransportOfUnregulatedBiologicalMaterials.aspx?tbID=fs>)

5.2.9.2 Shipping Of Biological Materials

For the purposes of shipping, biological materials may be classified as infectious substances (including “biological substances, category B” and “patient specimens”), biological products, genetically modified organisms, or medical/clinical waste. The shipment of certain genetically modified organisms is also regulated.

Infectious substances - Substances which are known or are reasonably expected to contain pathogens. Pathogens are defined as micro-organisms (including bacteria, viruses, rickettsiae, parasites, fungi) and other agents such as prions, which can cause disease in humans or animals. Infectious substances are now separated into the following categories:

Category A - An infectious substance which is transported in a form that, when exposure occurs, is capable of causing permanent disability, life-threatening or fatal disease to humans or animals.

Infectious substances meeting these criteria which cause disease in humans or both in humans and animals must be assigned to UN2814. Those which cause disease in only animals must be assigned to UN2900.

Assignment to UN2814 or UN2900 must be based on the known medical history and symptoms of the source human or animal, endemic local conditions, or professional judgment concerning individual circumstances of the source human or animal.

The proper shipping name for UN2814 is Infectious Substance, affecting humans. The proper shipping name for UN2900 is Infectious Substance, affecting animals. Figure 8 Packing and Labelling of Category A infectious Substances

Packing and labelling of Category A infectious substances

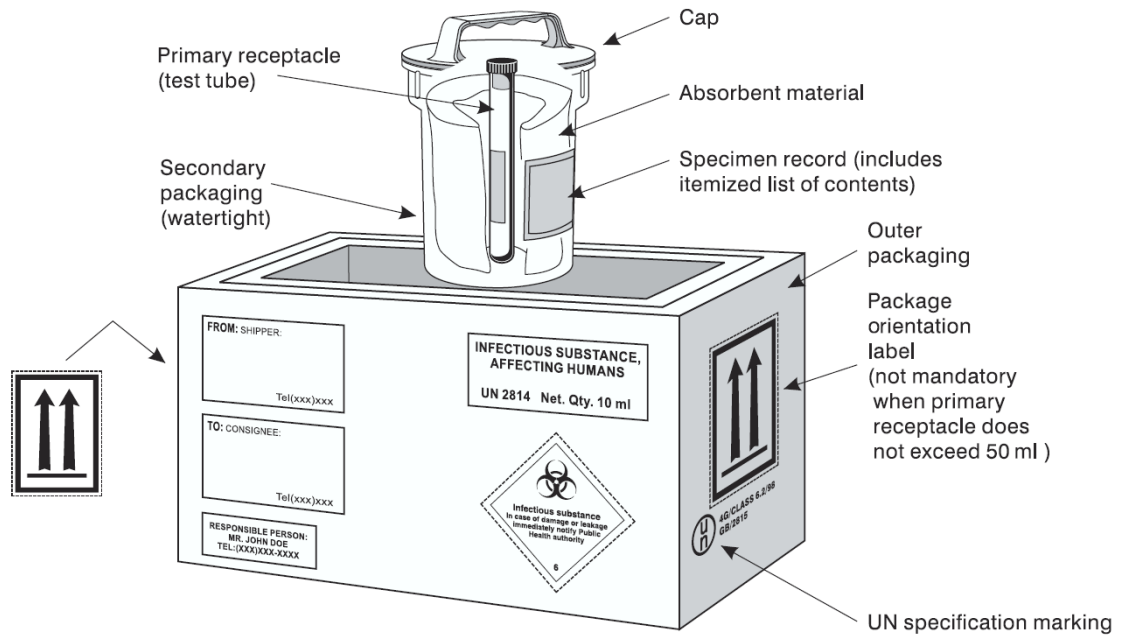


Figure 8 Packing and Labelling of Category A infectious Substances

Infectious Substances (Category A) Shipping Requirements

- Triple layer packaging (materials used for transport must be tested to ensure sample won't leak)
- Absorbent material
- Itemized contents list
- Outer package must bear Class 6.2 Infectious Substance diamond label
- Additional labeling and marking requirements
- Shipper's Declaration required

Category B - An infectious substance which does not meet the criteria for inclusion in Category A.

Infectious substances in Category B must be assigned to UN3373. Figure 9

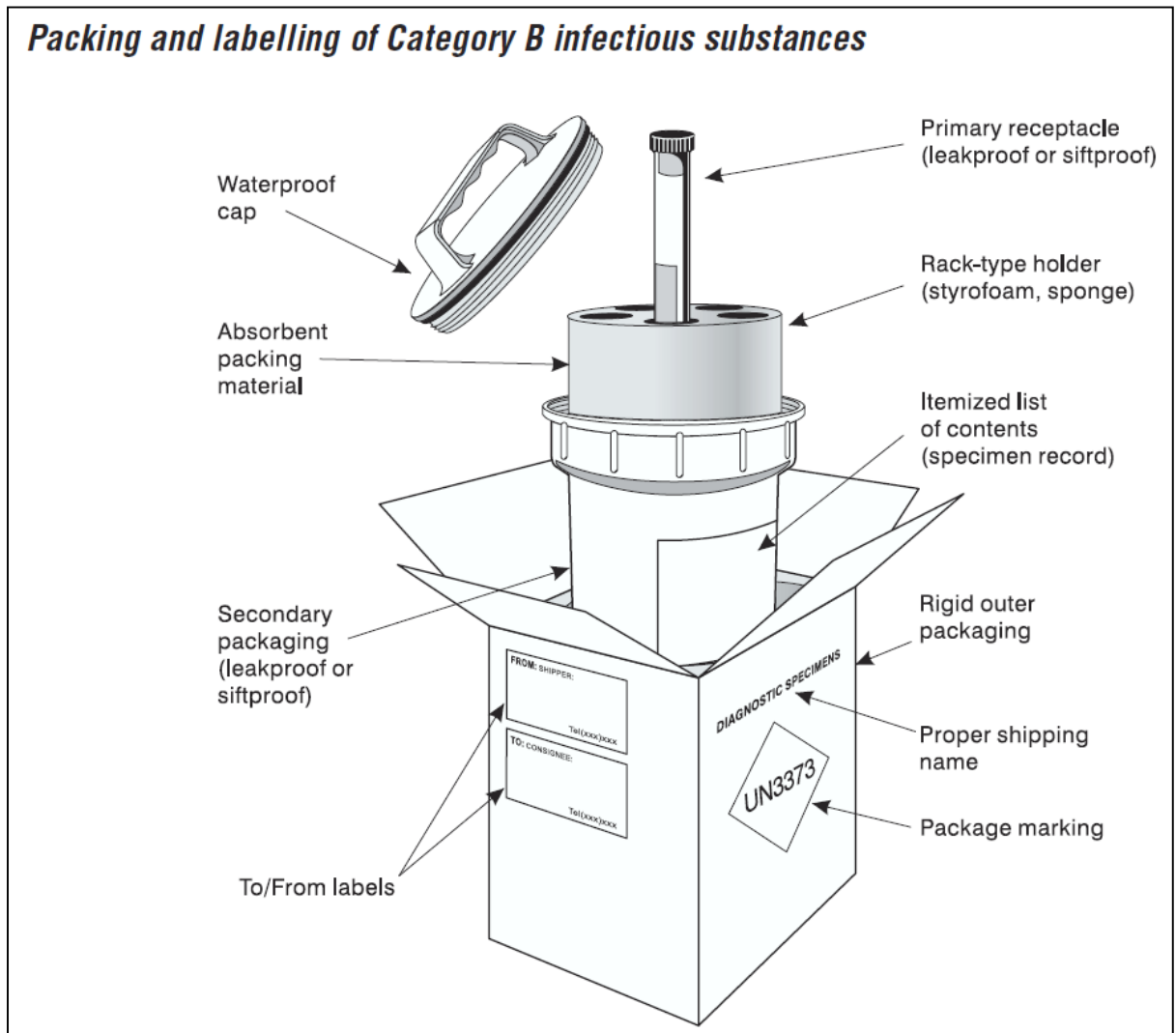


Figure 9 Packing and Labelling Category B infectious Substances

When transported, infectious substances (both Category A & B) are classified as dangerous goods and must be shipped in accordance with international (IATA) regulations.

- Infectious Substance, Category B Requirements
- Triple layer packaging
- Materials used for transport must be tested to ensure sample won't leak
- Outer package must bear UN3373 diamond label
- Outer package and air waybill must bear "Biological Substance, Category B" statement
- No Shipper's Declaration required; only airway bill
- Patient Specimens - Exempt specimens are those collected directly from humans or animals, for which there is a minimal likelihood that pathogens are present. Professional judgment should be used to determine if a substance is exempt. Examples include blood or urine tests for cholesterol levels, blood glucose levels, hormone levels, or prostate specific

antigens (PSA); tests required to monitor organ function such as heart, liver or kidney function for humans or animals with non-infectious diseases, or therapeutic drug monitoring; tests conducted for insurance or employment purposes and are intended to determine the presence of drugs or alcohol; pregnancy tests; biopsies to detect cancer; and antibody detection in humans or animals.

- Biological products - products derived from living organisms that are known not to produce viruses, toxins, etc. and are manufactured and distributed in accordance with requirements of national government authorities. These include, but are not limited to, finished or unfinished products such as vaccines. Biological products are not currently regulated for the purposes of shipping.²⁶

Please see the links below for further detailed information:

<http://www.searates.com/reference/imo/6.2/>

Dry Ice: In addition to the classifications and rules for potentially infectious materials, DOT and IATA regulate the shipment of **solid carbon dioxide, or dry ice**, as a dangerous good regardless of the hazard classification of any other materials in the package. **Dry ice** may cause burns, and if packaged improperly, can result in dangerously high pressure build-up inside of a sealed container. For these reasons, there are specific training, labeling, and packaging requirements for shipments containing dry ice.²⁷

Infectious Substance Shipments with Dry Ice Requirements

- Never place dry ice in a sealed container
- Outer package must be approved to hold dry ice, otherwise use an over pack
- UN 1845 Dry Ice label, including estimated weight of dry ice
- Class 9 Miscellaneous Dangerous Goods label²⁸

²⁶ <http://www.uth.tmc.edu/safety/biosafety/shipping.htm>

²⁷ <http://ehs.columbia.edu/transport.html>

²⁸ <http://www.uth.tmc.edu/safety/biosafety/shipping.htm>

6 SUNUM MICRO/NANO FABRICATION LAB (CLEANROOM)

6.1 Facility Hours

6.1.1 Micro/NanoFab Hours of Operation

SUNUM Micro/NanoFab operation hours are from 08:30 to 17:00 in working days. In normal operating hours the air extraction is high and meets safety and minimum contamination level requirements. For energy saving, in the weekday after hours, weekends and official holidays, the air extraction is maintained low; meaning that it meets the safety requirements yet, minimum contamination level is not guaranteed. Usage outside of the operating hours must be authorized by the Micro/NanoFab management.

If authorized, one can extend a room's "air extraction high" state by pressing the work in progress buttons inside the rooms. When pressed the button the green indicator at the top of the room entrance will light up and the room condition will continue in normal operation after the working hours as shown in figure below. Certain instruments and procedures may have restrictions during evenings and weekends (See Section 6.4.5 regarding the buddy system).



Figure 10 Work in progress button and indicator

6.1.2 Micro/nano Fabrication Lab Map

Figure 11 Figure 12

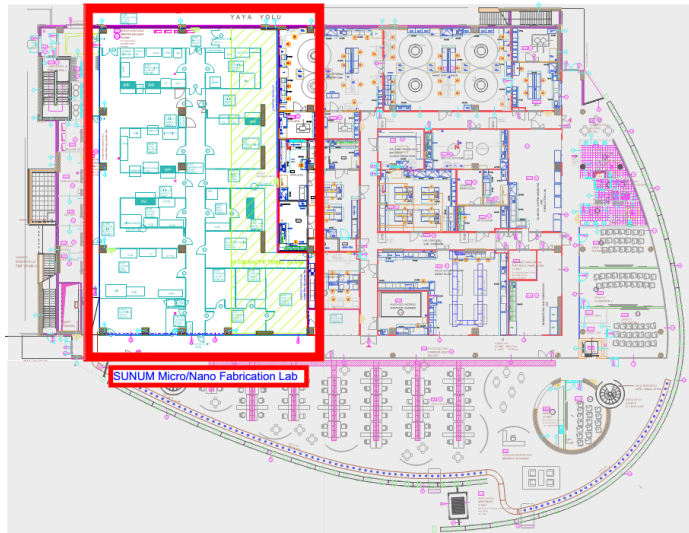


Figure 11 Micro/Nano Fabrication Lab Map

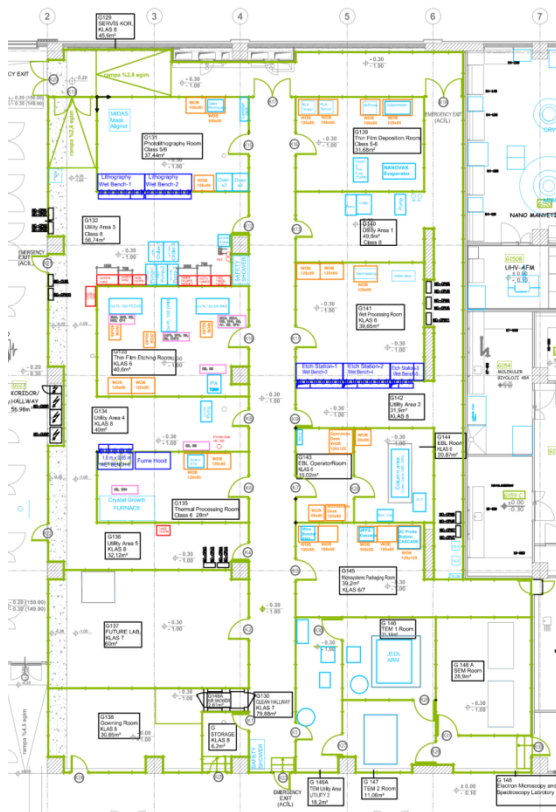


Figure 12 Sunum Micro/Nano Fabrication Lab

6.2 Communication

6.2.1 Website

The Micro/NanoFab website can be found at the address below;

<http://sunum.sabanciuniv.edu/laboratory/micronano-fabrication-clean-room>.

The website contains information about the Micro/NanoFab, equipment, safety, training, and information for new users.

6.2.2 Email

Much of the communication between Micro/NanoFab staff and users is done through email. All users must supply the Micro/NanoFab with a functional email address that they actively check for messages. Users give this information during the orientation process. In addition to communicating with individual users through email, all users are added to the Micro/NanoFab mailing list, sunumcr@sabanciuniv.edu. It is important to monitor email from this list, as it is the main source of announcements for training, lab closures, staff announcements, equipment problems, etc. Please do not use the Micro/NanoFab mailing list to send messages directly to Micro/NanoFab staff or other Micro/NanoFab users.

6.2.3 Laboratory Phone System

Telephones are provided throughout the cleanroom for the use by staff and users. There is a list of phone numbers containing emergency numbers, extensions for the SUNUM staff. This list is also available in the SUNUM website. The telephones can be used to call outside of the cleanroom to emergency numbers and Sabanci University extensions only. Off-campus calls cannot be placed from these phones. Cell phones are allowed in all areas of the facility however use is restricted in the following manner. Handsets should only be used in the Gowning Room to reduce laboratory contamination.

6.3 General Cleanroom Policies

6.3.1 Laboratory Access

Micro/NanoFab access is granted to those who have a need to work in the SUNUM Micro/Nano Fabrication Lab. To gain initial access to the Micro/NanoFab, one has to take the cleanroom training / orientation program which will be held by SUNUM Facilities Management. A test will

be conducted after successful completion of the orientation and users will be certified to use the facilities. A Micro/NanoFab access will be given (access right will be added to Sabanci University students/staff ID cards. An access card will be supplied for outside users) and nanofabrication cleanroom garment set will be issued when the training and entry requirements have been satisfied.

Access to the Micro/NanoFab is limited to those whose work requires cleanroom entry. Visitors may view the operations of the cleanroom through the touring corridor that has many viewing windows, which have been designed into the cleanroom perimeter.

Access to the Micro/NanoFab utility area from outside of the cleanroom is not allowed. Utility areas may only be entered from within the Micro/Nano fabrication cleanroom, and only SUNUM staff members or maintenance personnel are approved to enter the utility area. Exiting the cleanroom and/or cleanroom chases through the emergency exit doors is prohibited except in an emergency.

Access is only possible with the personalized key-card, giving you permission to those areas you are authorized to. It is not allowed to enter the clean room without using your personalized key-card by walking in with someone else or to take someone with you who has no key-card. Security Department requires unambiguous registration and monitoring 24 hours a day, via the entrance control system for all relevant areas.

It is not allowed to lend your key-card to somebody. In case you forgot your key-card, a spare can be obtained from the Facilities group for the time being. In case you lost your key-card, you should immediately inform the lab supervisor or Security so they can inactivate the key-card.

6.3.2 Dress Code

The dress code for working in the cleanroom is based on considerations of safety and cleanliness. The dress code is based on standard practices when working in clean areas that contain hazardous materials. The three components of the dress code include the street clothes that are worn under the cleanroom garments, the set of necessary cleanroom attire, and the personal protective equipment required when working with chemicals.

6.3.2.1 Street Clothes

In general, a user's clothing should be clean before entering the cleanroom. Users should not come to the facility with clothing that is dusty or dirty from previous work. Users should also avoid clothing that tends to shed a lot of fibers like fur, fake fur, mohair, etc.

Shirts must be worn and must extend from the top of the arms to the pants. Tank tops, halter-tops, and spaghetti strap tops are not allowed.

Pants must extend from the shirt to the ankles. Shorts, short pants, skirts, and dresses are not allowed.

In the summer months, putting on hospital scrubs over the top of shorts is popular.

Shoes must be closed toe shoes that fully enclose the heel and top of foot. High heels, sandals, open weave shoes, or shoes that expose the top of the foot are not allowed.

Caps, hats, and sunglasses are also not allowed.

6.3.2.2 Cleanroom Attire

When entering the cleanroom users are required to cover their street clothes with special cleanroom compatible garments. The purpose of these garments is to protect the cleanroom from contamination.

The cleanroom garments are not intended to protect the user from any hazardous materials found in the laboratory. The following list of garments must be worn in the cleanroom at all times:

- Hairnet or bouffant cap
- Eyeglasses, safety glasses, or goggles
- Face mask (during designated operations)
- Gloves
- Cleanroom gown or jumpsuit
- Shoe covers or cleanroom boots

A description of gown room procedures and policies is given in Section 6.5.1.

Safety glasses may only be removed when using optical microscopes. Users should be sure to remember to put them back on when they step away from the microscope. Safety glasses are not a substitute for face-shields when working with chemicals.

6.3.2.3 Chemical Safety Attire

When working with chemicals in the cleanroom, users are required to wear the following personal protective equipment:

- Chemical apron or smock
- Chemical visor or face shield
- Chemical resistant gloves

More information about chemical safety can be found in Section 6.7

6.3.3 Bringing Materials into the Cleanroom

Users are allowed to bring most materials into the cleanroom with a few restrictions:

No food or drink is allowed in the cleanroom, this includes chewing gum, cough drops, mints, candy etc. Eating and drinking is not allowed in the cleanroom.

Items not allowed in the laboratory are:

- Pencils
- Wood
- Cardboard
- Any material that will continuously shed particles

Other materials brought into the laboratory should be wiped with isopropyl alcohol to remove particles and finger oil. Equipment such as hotplates, power supplies, etc. brought into the laboratory must be approved in advance to determine location and duration.

6.3.4 Storage

Cleanroom space is a scarce resource; therefore, large amounts of storage are not available. A limited amount of storage space is made available to researchers. Typically a professor or company will be assigned a shelf in one of the storage cabinets located along the periphery of the laboratory. The shelves should be used only for keeping currently needed samples, masks, and tools. Please do not store unnecessary items such as, old samples, old masks, and unneeded samples.

No chemicals of any kind may be stored in user storage areas. Chemicals are to be stored only in the appropriate chemical cabinets. No additional dry boxes, desiccators, cabinets, etc. may be left in the laboratory without permission.

All items in the cleanroom should be clearly labeled with the user's name and the name of the user's research group and phone number. The staff periodically disposes of things left unlabeled, or belonging to inactive researchers.

6.3.5 Billing

All users of the Micro/NanoFab are charged by the hour for equipment usage. Equipment usage is determined from both the entries in calendars and logbooks of each equipment. Some expendables such as precious metals are charged by the amount used. The current rates for laboratory time and equipment charges can be found in the current rate sheet. User fees pay for the operations of the Micro/NanoFab including staff, expendables, equipment maintenance, and upgrades.

6.3.6 Citation Suggestions

Although not required, the SUNUM Micro/Nanofabrication Lab would appreciate an acknowledgement in research publications that have devices fabricated in the Micro/NanoFab. The goal of such an acknowledgement is to promote SUNUM and Micro/NanoFab facilities for the betterment of the University. An example of an acknowledgment is given below:

“The authors would like to thank the Sabanci University Nanotechnology Research and Application Center for making the fabrication of this device possible.”

If you choose to acknowledge the Micro/NanoFab, thank you, we appreciate it.

6.4 Equipment Policies

After a user has completed the orientation process, been issued a badge, and can enter the cleanroom, the user is generally not qualified to use any of the processing tools and must undergo additional training. Most of the equipment in the cleanroom is setup to be operated by users rather than equipment operators. Although there are no dedicated operators to run processes for users, each piece of equipment is under the responsibility of one faculty member and one SUNUM staff member. Current equipment responsibilities can be found on the equipment pages in SUNUM website.

Equipment policies regarding allowed and prohibited operations on the tool are developed by the responsible engineers and laboratory management and set down in the written operating procedure for that tool. Operating procedures, or specs, can be found in the equipment logbooks as well as on equipment pages in SUNUM website. Violation of the written procedures or careless operation can result in damage to the equipment, downtime and considerable expense. Therefore, careless use leading to equipment damage will result in possible suspension of user privileges, charges related to equipment repair, and require the user to perform additional laboratory service.

6.4.1 Equipment Training

Before using any piece of equipment in the Micro/NanoFab, users must undergo additional training specific to that piece of equipment. Depending on the complexity of the tool there can be more than one training sessions.

For efficiency, a group of users are trained at one time in the first training session. In the first session the super-user or responsible engineer shows the users how to operate the equipment by following the operating procedure and pointing out additional processing rules and potential pitfalls. For less

complex equipment this first training session is all that is needed for the user to start using the equipment.

For more complex equipment, a qualification or certification training is required of all users. The second training session is a one-on-one session where the user demonstrates that they can operate the tool in an independent fashion. The super-user or engineer watches the user independently operate the tool and evaluates whether or not the user can safely use the tool without supervision. It is recommended that a qualification run be scheduled when the user has a real sample to process. In this way the user can get advice on the best recipe to use and potential pitfalls related to their specific sample.

6.4.2 Equipment Logbooks

Each piece of equipment has a logbook associated with it. Users must fill out the information in the logbook every time a piece of equipment is used. You will be shown how to fill in the logbook during equipment training. The information provided by the user entries in the logbook is necessary component of documenting equipment usage. The engineer responsible for a piece of equipment will monitor the log entries several times a day in order to determine the status of the equipment, problems users may be experiencing, and process drift. Accurate and complete information is necessary for the engineers to keep the equipment running and identify small problems before they become big problems.

6.4.3 Problems with Equipment

Problems with the operation of the equipment should be reported to the principal equipment engineer in charge of the tool. If the problem occurs during staff hours calling the equipment engineer on the phone or finding them in the laboratory is the best solution. If the problem is after hours, it is important to send an email to the engineer describing the problem.

For equipment that is not operational or may be dangerous to continue operation, such as having a wafer stuck in the chamber, the user should prominently attach a note to the front of the tool describing the situation. This makes certain other users going to use the equipment are warned of the problem and not to use the equipment. If the problem occurs after hours, the user will have to wait until the next business day for a resolution.

In no cases should a user attempt any repairs to the tool beyond what is explicitly allowed in the operating instructions for the tool. As with all things, if a user is uncertain if it is OK, they should

check with staff before taking action. The equipment in the facility is very expensive and much of it is very delicate. Considerable damage can be done at a great cost of both money and downtime by careless attempts to fix things.

Users should not call the staff at home in the evenings or on weekends about problems with the equipment or their process. It will have to wait until the next workday. Obviously, major problems like fire, smoke, significant water leaks, or alarms should be reported immediately.

6.4.4 Reserving Equipment

Equipment can be reserved for a specific period of time through the calendar of the related equipment. Equipment reservations give the user priority for using the tool and are provided as a means to efficiently schedule heavily used equipment. The calendar is web-based and accessible from any computer with a web connection. Most equipment has a maximum amount of time, typically 3 hours, a user can reserve the tool in a given day. This restriction is to allow all users access to a tool within a reasonable time span.

If a user is going to be late for a reservation, they should delete and reschedule their time on the tool. In order to reduce last minute cancellations, users are not allowed to cancel a reservation within two hours of the beginning of the reservation. In the event a user needs to cancel the reservation during the two-hour period before the start of the reservation, the user should send a message to the Micro/NanoFab mailing list to notify other users as to the cancellation. The Micro/NanoFab understands that all projects require a certain process flow between instruments so that one problem can throw off an entire process schedule. Also, processes can take longer than anticipated. Thus while it is encouraged to sign up ahead of time, users should also be flexible and cooperative with other users in stretching, sharing, and relinquishing time slots. Users who repeatedly cancel reservations after the two-hour deadline will be charged the minimum usage fee for that tool if no one uses the tool in their place.

If a user is more than 15 minutes late for his or her reserved time on a tool, the reserved time may be claimed by anyone in the lab.

6.4.5 Buddy System

Use of the Micro/Nano fabrication lab requires that two users be in the cleanroom at all times. During normal staff hours this requirement is generally satisfied by the presence of the staff. Outside normal business hours it is necessary to ensure that you are not working alone in the laboratory. It is the user's responsibility to coordinate with another user to ensure that two people are in the laboratory.

Your buddy should:

- Know what you are doing and when you are doing it.
- Be within 10 feet of you if you are using HF or BOE.
- Be in the cleanroom or chase during other processing activities (not necessarily in the immediate area) and check in on you every 30 minutes
- Know what to do in case of an emergency.

6.4.5.1 Normal Working Hours

During normal working hours, you can find out how many people are in the lab by checking the ID board. Talk to one of them, and agree to be “buddies”. When leaving the lab, notify your buddy so a new arrangement can be made. If you are the second last person out of the lab for lunch or the day, it is your responsibility to notify the last person and wait for them. It is the last person’s responsibility to leave as soon as possible.

6.4.5.2 After Hours

This policy applies only to qualified users of the machines involved who also have 24 hr lab access. Apprentice users or those with restricted lab access are expected to use the facility during normal hours of operation.

Lab activities have been divided into 3 categories.

1. No after-hours activity permitted:
 - a. PECVD
 - b. Metal – III-V ICP RIE
 - c. CVD furnace or RTA
2. Safety buddy must be WITH YOU IN THE ROOM during the activity:
 - a. HF and BOE solutions
 - b. Hot piranha solutions (both acid and base types)
 - c. Metal etches (Cr, Al, Au, Ti)
 - d. Silicon etches (KOH, TMAH, EDP)

- e. Equipment repair in high voltage areas
 - f. Wafer saw
3. Safety buddy checks in on you every 30 minutes (within-building phone checks permitted):
- a. E-beam evaporator or thermal evaporator repair / maintenance / use
 - b. RIE (standard processes only)
 - c. Lithography (standard photoresists; spinning, expose, develop)
 - d. High temperature ovens (standard oxidations and anneals)
 - e. Metrology and Testing tools

6.4.6 Process Repeatability and Reliability

The Micro/NanoFab is a shared use facility where users perform a wide variety of research. Because of this, the process flows and projects that users perform in the laboratory are quite varied. The minimum feature size, photoresists, etch depths, number of layers, layer composition, open area, backside condition, cleanliness, metals, etch stops, masking materials, chemistry, etc are different from user to user.

If you will try any process different than standard processes please consult to the superuser of the equipment

For a processing tool to give reliable and repeatable results, not only do the processing parameters and conditions need to remain constant from run to run, but also the condition of the processing chamber. There

is interplay between the machine condition, wafer preparation, and processing parameters that make a process stable and reliable. If you change any one of these factors the end result of the process will most likely be somewhat different.

When processing inside the Micro/NanoFab, users have direct control over the processing parameters and wafer preparation, but often do not have much information about the internal condition of the processing chamber. The condition of the processing chamber is particularly important for etch tools. Over time the performance of processing equipment degrades due to build-up of processing by-products. For equipment to run in peak performance it needs to be periodically cleaned, both physically, by scrubbing the chamber by hand and chemically by running the tool with a cleaning recipe.

The Micro/NanoFab staff performs periodic physical cleaning of the tools, but users can perform the chemical cleaning of the chamber, generally accomplished by running O2 plasma in an RIE machine. While cleaning helps to remove unwanted material from the process chamber, the cleaning process leaves the chamber in an unstable state, which starts to change as a regular process is run in the machine. For this reason, it is typically necessary to perform a conditioning or seasoning run to eliminate this first wafer effect for your samples.

In a seasoning run, the chamber is lightly coated with the by-products of the real processing recipe. The conditioning run should be run using the same recipe and wafer preparation as the next lot of wafers to be run. After a conditioning run you can be relatively sure that the condition of the chamber is in a known, reliable, and well controlled state. In order to confirm that the tool will generate the expected results, a process monitor wafer should be run to verify the etch rate, deposition rate, etc. Only then can you be confident that the tool will give the expected results for the next wafers in your lot.

6.5 Cleanroom Procedures

In order to enter the cleanroom, users must be properly dressed and follow the procedures for gowning in order to avoid generating unnecessary particles. Proper cleanroom etiquette is important to ensure the cleanliness of the cleanroom and maintain the ability to perform state-of-the-art experimental work. Section 6.3.2 covers the general dress code for the facility. Even if a user determines that their work is not sensitive to particles, it is important to recognize that this is a shared-use environment where other researchers need a clean facility. If you are uncertain what the proper protocol for a situation is, talk with staff before proceeding.

Every time material is brought into the cleanroom, contamination is carried along with it. One aspect of maintaining the cleanliness of the cleanroom is to minimize the amount of material brought into the facility. Therefore, only items needed should be brought into the cleanroom. Section 6.3.3 covers the items that are expressly forbidden from the cleanroom. It is important for the user to become familiar with these restrictions and come appropriately prepared for working in the cleanroom.

6.5.1 Cleanroom Garment Protocols

A cleanroom suit consists of three parts: a hair net, a gown, and shoe covers. Proper gowning technique is important to ensure the cleanliness of the garments and the facility. Before entering the cleanroom, users should make certain they meet the clothing requirements listed in Section 6.3.2.

The gown room consists of a dirty area and a clean area separated by a bench. When you enter the gown room you will be on the dirty side where street shoes can be worn. On the other side of the bench, is the clean area, only shoe covers or clean shoes should be worn on this side of the gown room. It should be noted that the cleanroom suit is not designed to protect users from potential hazards in the cleanroom, but rather to protect the cleanroom from particles generated by the users clothing, skin, and hair. Protective safety equipment must be worn when handling chemicals.

To enter the cleanroom:

- i. Step on the tacky mat at the cleanroom entrance to remove dirt from the bottom of your shoes. Don't worry if it looks dirty, it is still working.
- ii. Put on shoe covers or clean shoes and hair cover and step over the bench to the clean side of the gown room.
- iii. Put on the cleanroom gown being careful not to drag the gown on the floor in the process.
- iv. Put on a facemask if required.
- v. Put on boot covers and step over the second bench towards the air shower.
- vi. Put on gloves and tuck the sleeves of your gown into the gloves.
- vii. Then put on your safety glasses.
- viii. Step on the tacky mats in front of the air shower
- ix. Enter the air shower and wait until the air blow ends

Once in the cleanroom, the cleanroom suit should never be opened or unzipped. If something under the suit is needed, return to the gowning room to open the suit and retrieve it. Anything that a user needs access to while in the cleanroom should be taken out while in the gown room and wiped down with isopropyl alcohol.

When exiting the cleanroom, reverse the steps used to gown.

- i. Place the gown on a hanger and label it by writing your name on a piece of tape and attaching it to the hanger.
- ii. Snap the boots to the bottom of the pant leg.
- iii. Throw away the facemask, gloves, and hairnet.

Continue to reuse the gown upon each entry. After approximately five uses, all cleanroom garments (including hoods, jumpsuits, and boots) should be deposited in the designated receptacles for laundering or thrown away (if using disposable). When using a gown for the first time, it should be inspected for holes or tears, do not worry about stains or discoloration.

6.6 Facility Hazards

6.6.1 Laboratory Hazards

The Micro/NanoFab uses various chemicals that can pose a health hazard for users. These laboratory chemicals generally fall into two categories: gases and wet chemicals. There are also some hazardous solids such as sharps and GaAs. Many processing tools in the facility use compressed gases to operate, some of which are toxic, highly toxic, corrosive, flammable, or explosive. Due to the hazards posed by these gases they are strictly contained and controlled because an accident with these gases can be catastrophic. The hazards created by compressed gases, however, are greatly minimized by the use of proper equipment, proper confinement, ventilation, sensors, purges, safety valves, etc.

Wet chemicals present a more troublesome category of hazard. Users commonly use acids, bases and solvents in a “hands on” way, and therefore, the risks are in the hands of each individual user. Because many wet chemicals are considered common and are used routinely by many users, they present a serious hazard due to familiarity and reduced vigilance of safety procedures. Many of the wet chemicals commonly used in the facility can cause severe burns, tissue damage, organ damage, asphyxiation, and genetic damage if improperly used. These chemicals can enter the body by inhalation, ingestion, or absorption (either directly through the skin or through gloves) and may have either long or short-term health consequences. In addition, improper use of solvents can result in a major fire. In short, ordinary, routinely used wet chemicals in the laboratory are not hazard free. Users are expected to treat all chemicals with appropriate respect, and to be aware of all possible reactions, which may be created, either intentionally or by accident.

6.6.2 Where to Find Chemical Information

The Materials Safety Data Sheet (MSDS) is a convenient, condensed source for information on the properties of chemicals. The MSDS is a federally mandated document, which must be supplied by the manufacturer or vendor of a chemical. It contains in summary form, the chemical composition, the physical and chemical properties, toxicology data, and instructions for handling, spill control, and waste disposal. Users must read the MSDS for every chemical that they handle inside the cleanroom. Detailed information about MSDS sheets and the source to find them is given in Appendix F of SUNUM Health and Safety Document.

6.6.3 Bringing New Chemicals into the Laboratory

Only specifically authorized chemicals may be used in the laboratory. Most standard processing chemicals have been pre-authorized; such as acetone, isopropyl alcohol, methanol etc. No other chemicals may be brought into the facility without prior authorization.

Users who want to bring a chemical into the laboratory that is not already pre-approved (i.e., already in the MSDS binder) must submit two copies of the MSDS sheet to facility management for review. Approval of new chemicals is not guaranteed and may take some time for staff to address issues such as chemical compatibility, waste disposal, and other issues. Researchers should refrain from purchasing chemicals until approval is granted.

If your chemical is approved for use in the laboratory the laboratory staff will show you where to properly store the bottle in one of the chemical cabinets in the laboratory. When storing chemicals in the laboratory users must label the bottle with the following information: Figure 13

- Professor or Company Name
- User name
- Date the chemical was brought into the laboratory

6.6.4 Toxic and Corrosive Gases

The Micro/Nano Fabrication Lab uses small quantities of pyrophoric and toxic gases. The following section covers some properties of the major hazardous gases used in the facility. This list is not necessarily exhaustive but is meant to cover the major gases and the major hazards present in the facility. Detailed information on the gases used in SUNUM is given in Appendix D and E of SUNUM Health and Safety Document.

6.6.4.1 Silane

Silane (SiH_4) is used for the deposition of silicon nitride and silicon dioxide in the PECVD system in G133. Silane is pyrophoric, meaning it will spontaneously ignite in air or water vapor at concentrations between 2% and approximately 90%. It produces a white powder (glass) as a byproduct of its burning which is non-toxic. The silane gas cylinder is located in fully automatic gas cabinet which is in G132 Utility area 3 of Micro/NanoFab.

6.6.4.2 Chlorine and BCl₃

Chlorine and BCl₃ gases are used in Oxford ICP/RIE etcher in G133 and stored in fully automatic gas cabinet in G132 Utility area inside the Micro/NanoFab. They are greenish-yellow in color and are strong oxidizers with a choking odor. Chlorine is in a double contained tube (tube within a tube) because of its toxicity. Chlorine forms HCl acid in the lungs, causing severe tissue damage, which can be fatal. As with many other corrosive gases, the effects of exposure may not be noticed for a few days. In all cases, medical attention should be sought immediately following exposure, not at the onset of symptoms. For your reference the following values relate to chlorine exposure.

TLV: 1 ppm

Odor Threshold: 0.1 ppm

Coughing: 30 ppm

Dangerous in 30 min: 40-60 ppm

Fatal with a few breaths: 1000 ppm

Because of the small amounts used, the ventilation used, and the low odor threshold for chlorine exposure, accidental chlorine gas exposure is not considered a significant risk.

6.6.4.3 Anhydrous Ammonia

Ammonia is used in the PECVD system in G133. Anhydrous Ammonia (NH₃) is a severely corrosive alkaline vapor with a pungent odor. Ammonia is flammable in the 15-28% concentration range. Ammonia exhibits good warning properties, with an odor threshold of 50 ppm. Although the TLV is only 25 ppm, concentrations up to 300 ppm can be tolerated for an hour. Concentrations above 3000 ppm are suffocating, causing convulsive coughing and respiratory spasm. Such exposures can rapidly be fatal.

6.6.4.4 Hydrogen

Hydrogen is a flammable, colorless, odorless, compressed gas packaged in cylinders at high pressure. It poses an immediate fire and explosive hazard when concentrations exceed 4%. It is much lighter than air and burns with an invisible flame. High concentrations that will cause suffocation are within the flammable range and must not be entered. Hydrogen is used in ICP/RIE Etcher in G133 and CVD furnace and Rapid thermal annealer in G135.

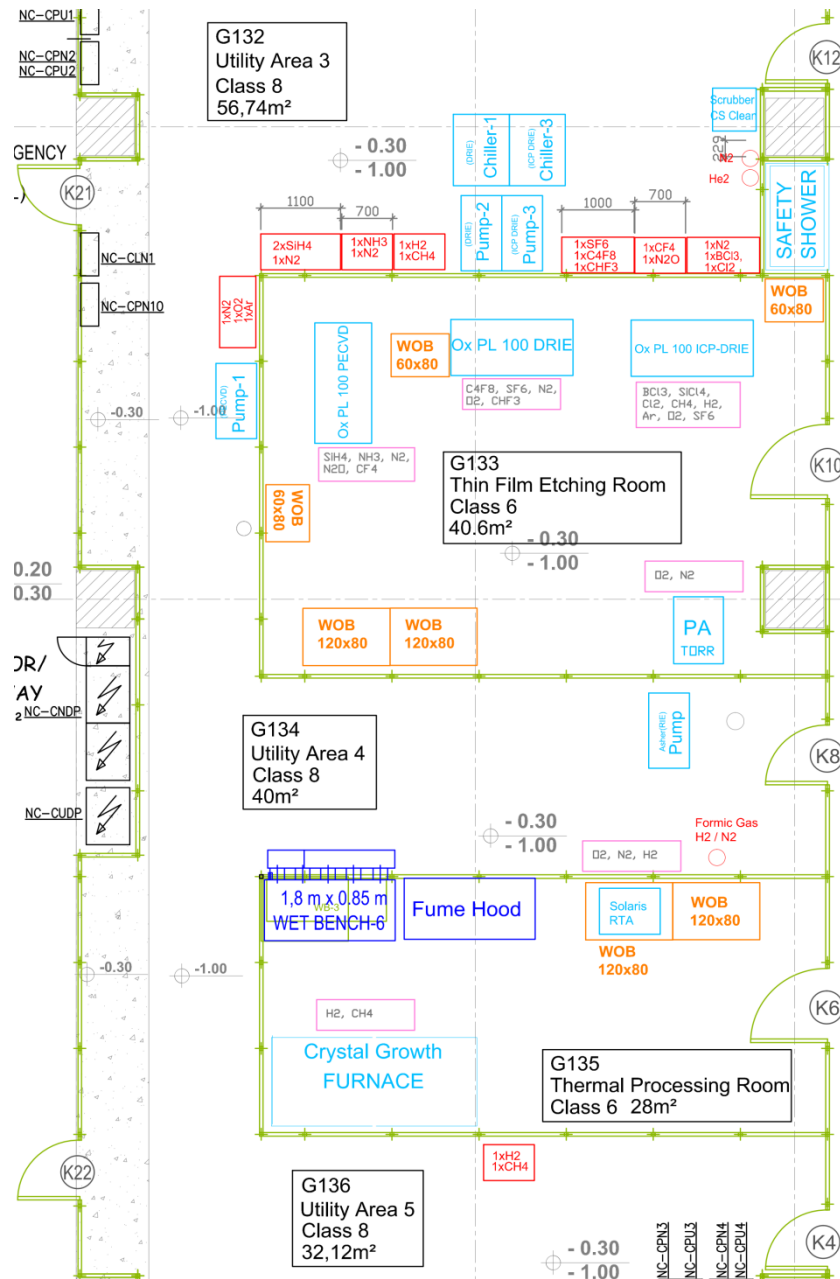


Figure 13 Process cabinets and gases used in cleanroom

6.6.5 Gas Monitoring And Control System

The gases used within the facility for processing are generally supplied under high pressure from compressed gas cylinders. Most of these gases are kept in gas cabinets placed in G132 Utility Area 3 in SUNUM Micro/Nano Fabrication Lab. Gas cabinets are special cabinets that have exhaust units for small leaks and the ones that have toxic or flammable gases are equipped with detectors to detect the leaks. These cabinets are specially designed to accommodate the toxic and flammable gases used in the Micro/NanoFab and they are kept locked at all times and may only be opened by trained personnel.

The gases are piped into the cleanroom from the service area in specially welded steel tubes that have been helium leak checked and are connected directly to various tools in the cleanroom. Gas sensors are strategically located to sense the smallest leak. Under a high alarm condition, the sensors shut off the gas, sound a building alarm and send an emergency situation message to the University security department.

Below is a list of the safety precautions that have been implemented for toxic gases.

- Gases are stored in an exhausted specially-designed fully or semi automatic gas cabinets
- Orbital-welded stainless steel tubing is used in all process gases. Coaxial SS tubing is used in toxic and flammable gases
- An integrated gas detection system capable of sensing extremely small amounts of each gas. If a gas leak is detected, an alarm is activated and a fire dispatch signal is sent automatically.
- Pneumatic valves to shut the gas bottle down in the event of a leak.
- Flame detectors to detect flammable gas leaks

6.6.6 Specific Chemical Hazards

Here is an overview of some specific or unique hazards from some chemicals commonly used throughout the facility. Users should review the MSDS for these and any other materials they work with.

6.6.6.1 Acetone and Flammable Solvents

Acetone is widely used throughout the facility. It is a very flammable solvent with a low flash point, (i.e. it can be ignited at a low ambient temperature). Because of this it is a significant fire hazard. A spilled gallon bottle of acetone could cause a catastrophic fire or explosion. Solvents should also be handled with care in the hoods and are not to be used near hot plates as spilled solvents can be ignited by hot plates. Spilled solvents can also react explosively with chemical oxidizers such as peroxides and acids. Spilled solvents should be contained immediately with spill control pillows.

6.6.6.2 Hydrofluoric Acid

Hydrofluoric Acid (HF), a weak acid, is a very hazardous chemical, much more so than any of the other acids. Micro/NanoLab users must obtain special training before using HF. Its danger comes from its destructive effect on the tissues of the body. At many concentrations used in the laboratory,

an HF “burn” is initially painless. The person may not even know that they have gotten a splatter on their hands, arms, face, or on their gloves. The delayed sensory reaction of the body to HF exposure is one of the main dangers of the acid. Considerable damage can occur before the person is aware of the exposure and mitigates it.

Upon exposure, the HF acid causes considerable tissue damage as it works its way through the skin and into deeper tissues. While penetrating the skin the fluoride ion is not consumed and becomes soluble in tissue and penetrates deeper and deeper, until it comes to the bone. After HF has penetrated deeply it is too late to reverse the considerable tissue damage. At some point, it enters the blood stream scavenging Ca^{+2} ions, and alters the ionic chemistry of the nervous system. If left untreated, serious injury or death will result.

HF burns are a unique clinical entity. Dilute solutions penetrate deeply before dissociating, causing delayed injury and symptoms. Burns to the fingers and nail beds may leave the overlying nails intact. Severe burns are those following exposure to concentrated HF (50% or greater) to 1% or more body surface area, HF of any concentration to 5% or more body surface area, or inhalation of HF fumes from a 60% or stronger solution. The vast majority of cases involve only small areas of exposure, usually on the digits.

Tissue damage is caused by two mechanisms, a corrosive burn from the free hydrogen ions and a chemical burn from tissue penetration of the fluoride ions. Fluoride ions penetrate and form insoluble salts with calcium and magnesium. Soluble salts are also formed with other cations but dissociate rapidly, releasing the fluoride ion allowing further tissue destruction.

The time to onset of symptoms is related to the concentration of the HF:

- Solutions of 14.5% produce symptoms immediately.
- Solutions of 12% may take up to an hour.
- Solutions of 7% or less may take several hours before onset of symptoms, resulting in delayed presentation, deeper penetration of the undissociated HF, and a more severe burn.
- Concentrated solutions cause immediate pain and produce a surface burn similar to other common acids with erythema, blistering and necrosis.
- The pain is typically described as deep, burning, or throbbing and is often out of proportion to apparent skin involvement.

Physical:

- Weaker solutions penetrate before dissociating.
- Surface involvement in these cases is minimal and may even be absent.
- Three categories of appearance:

- A white burn mark and/or erythema and pain
- A white burn mark and/or erythema and pain, plus edema and blistering
- Ocular burns present with severe pain.
- Inhalation burns may develop acute pulmonary edema.

Simple washing of an HF splash is not sufficient to prevent damage. It does not wash off, but rather penetrates the skin and will continue to do damage until medical attention specific to HF burns is given (including deep injections to neutralize the penetrated acid). Be sure that medical personnel know that it is an HF burn and know that it requires specific treatment different from a common acid burn.

The recommended first aid for HF exposure consists of the following steps:

- Remove any contaminated clothing making sure not to create secondary exposure
- Rinse the exposed area with copious amounts of water for 5 minutes
- Recruit other users in the lab to help and notify laboratory management
- Apply Calcium Gluconate gel, stored in all the first-aid, HF cabinets, and waste cabinets, liberally to the affected area. Reapply every 15 minutes. Wear gloves when applying the gel to prevent transfer of HF and secondary burns. If exposure is to the hand, Calcium Gluconate can be placed inside a clean glove to soak the affected area.
- Seek medical attention and make sure to inform the emergency room personnel that it is an HF burn and must be treated differently than other chemical burns.

HF etches silicon dioxide very well. Therefore, it also etches glass. It must not be kept in a glass bottle, used in a glass beaker or disposed in a glass waste bottle. HF, like all other chemicals, must only be used in the chemical hoods.

6.6.6.3 Piranha Etch and Nanostrip

Piranha etch is a common name applied to a heated mixture of Hydrogen Peroxide and Sulfuric Acid (typically 1:2 to 1:5). It is extremely aggressive toward organic materials (e.g., biological tissues and photoresist residue, equally). It also removes heavy metal contamination. It is commonly used in the semiconductor industry and this laboratory for wafer cleaning.

As with all H_2O_2 containing solutions, when disposing of Piranha it is important to use a waste bottle with a vented cap as the waste continues to react and decompose for a long period of time. This can build up pressure in an un-vented waste bottle causing it to burst. Piranha solutions should be allowed to cool to room temperature before pouring into a waste container. Also if the solution is very peroxide

rich, one can make unstable compounds. Nanostrip is a commercial stabilized version of Piranha that the laboratory uses for aggressive mask cleaning.

6.6.6.4 Tetramethylammonium Hydroxide

Tetramethylammonium Hydroxide (TMAH) exists in several different forms in the cleanroom. The most common usage is in dilute (<4%) aqueous solutions for developing photoresists. These developers are often referred to by their brand names, so it can be hard to determine without the MSDS, which developers contain TMAH and which are based on other bases.

Some Micro/NanoFab users use concentrated TMAH in water (~40%) for selective etching of silicon. TMAH in this form is significantly more hazardous than the dilute solutions used in the lithography areas. In addition to the corrosiveness of the material, concentrated TMAH is also highly toxic. The increase in toxicity of concentrated TMAH is much more than the increase in concentration. It is important for users to treat the concentrated material with much more caution, and not view it as simply a more concentrated developer.

6.6.6.5 Chlorinated Solvents

Chlorinated solvents (chlorobenzene, trichloroethylene, and methylene chloride) are used in various resist processes. They are particularly bad for the human body, causing cancer, organ damage, etc. If possible these solvents should be avoided for example by using a special lift-off resist rather than chlorobenzene. They should not be mixed with normal solvents in waste bottles. Users must use separate waste bottles for chlorinated solvents. As with most solvents, they can be readily absorbed through the skin. Chlorinated solvents (e.g., Methylene Chloride and Chlorobenzene) do not rinse well from bottles and other glassware. To properly remove the solvent residue from the containers, the container should be thoroughly rinsed with Isopropanol, with the rinse going into the Chlorinated Solvent waste bottle. The item should then be rinsed with water, which may go down the drain.

6.6.6.6 Glycol Ethers

Commercial photoresists and electron beam resists are dispersed in a variety of solvents. The composition of these mixtures is generally not disclosed on the bottle; you must look on the MSDS for it. One family of chemicals, the glycol ethers, is commonly used in photoresists, and has a variety of trade names, which are again all identical.

Most photoresists contain one or more glycol ether as solvents. The present solvent of choice is PGMEA (propylene glycol mono methyl ether acetate) also known as 1 Methoxy-2-propanol acetate. Members of this family of chemicals have been shown to be teratogenic and have other effects on reproduction in laboratory animals. A number of recent studies funded by IBM and others have found evidence that these chemicals can lead to miscarriage and other reproductive effects. To quote from the MSDS for AZ 2131 Thinner (2 Ethoxyethyl Acetate and N-Butyl Acetate) “In studies with laboratory animals, 2-ethoxyethyl acetate caused birth defects, increased fetal death, delayed fetal development, caused blood effects, testicular damage and male infertility.” The liquid and vapor are eye and respiratory tract irritants and may cause kidney damage, narcosis, and paralysis (in simple terms, it damages your kidneys, eyes, lungs, and brains). Primary routes of exposure are inhalation, skin absorption, and skin and eye contact with vapors. N-butyl Acetate, the other component of this thinner, has a similar list of possible systemic effects. These experimental laboratory exposures were large amounts but nonetheless it is prudent to be careful with these solvents.

6.6.6.7 Peroxides

All peroxides are highly oxidizing materials. Considerable energy can be released in their reactions with common materials. Some peroxide compounds are unstable, and can explode. The Hydrogen Peroxide in the facility is over ten times more concentrated than the solution used in the medical field and has a high contact risk. Extreme care should be used in mixing solutions containing peroxides. Peroxides are incompatible with all forms of organic solvents and flammable materials.

Users should be careful when disposing of pure hydrogen peroxide solutions in waste bottles. Adding pure hydrogen peroxide to an ammonium hydroxide / hydrogen peroxide or hydrochloric acid / hydrogen peroxide waste bottle can lead to rapid heating and breakdown of the peroxide, which can result in the waste bottle being over pressurized and rupturing.

When disposing of peroxide solutions it is important to use a waste bottle with a vented cap as the waste continues to react and decompose for a long period of time. This can build up pressure in an un-vented waste bottle causing it to burst.

6.6.7 Pregnancy

Users who believe they to be pregnant should discuss laboratory use with the management as soon as possible. This need not severely restrict laboratory use but should nonetheless be discussed.

6.6.8 Asthma, Rashes, or Unexplained Symptoms

If after using the Micro/NanoFab you experience unexplained health effects such as difficulty breathing, asthma, rashes, or other symptoms that cannot be explained users should notify the Nanolab staff so that cause can be determined. If symptoms are severe, users should immediately seek medical attention and inform the medical personnel what chemicals and processes the user may have been exposed to.

6.7 Using Wet Chemicals

Wet chemical processing is one of the most dangerous aspects of working in the Micro/NanoFab. The danger is not only derived from the strength and reactivity of the chemicals used, but also by the direct interaction that users have with the chemicals. The policies procedures laid out in this section are designed to keep users safe, even in the event of an accident. However, the procedures are only effective as long as they are routinely followed and implemented with common sense. Failure to follow chemical handling procedures is a serious violation of laboratory policy and can result in permanent expulsion from the laboratory.

6.7.1 Chemical Supplies

The facility supplies chemicals commonly required for processing in the facility. In order to preserve space in the chemical cabinets, users are discouraged from bringing in their own stocks of supplied chemicals. Working stocks of chemicals are kept in the cabinets below the wet benches. Users must not restock a chemical until all opened bottles in a cabinet are completely emptied. Do not use chemicals that have a label indicating they belong to another user, call the user first. Please refer to Section 5.3 for information on bringing new chemicals into the laboratory.

Chemical bottles carried from room to room or from isle to isle in the laboratory must be carried in a PP chemical carrying chart. Users carrying bottles within a single room or isle are not required to use the chart. All chemical containers moved outside of a wet bench or fume hood must be sealed with a screw top lid. Open containers or containers with unattached lids may not be carried around the lab, even if

they only contain water. Users must not open a new bottle until the old one is empty. When a chemical bottle is emptied, it must be properly taken care of before a fresh supply of chemical is retrieved.

6.7.2 WET BENCHES & Fume Hoods

The Micro/NanoFab classifies the wet benches into two groups: general use wetbenches, and designated wet benches. There is one general use wet bench and one general use fume hood located in the laboratory. General use hoods do not need any special training and can be used immediately after a user has completed the safety walkthrough. General use hoods can be used for processing with acids, bases, and solvents.

Before using any wet bench or fume hood it is necessary to check that the hood is properly venting. Typically all the wet benches in the cleanroom are equipped with a knob to adjust the wet bench for three states.

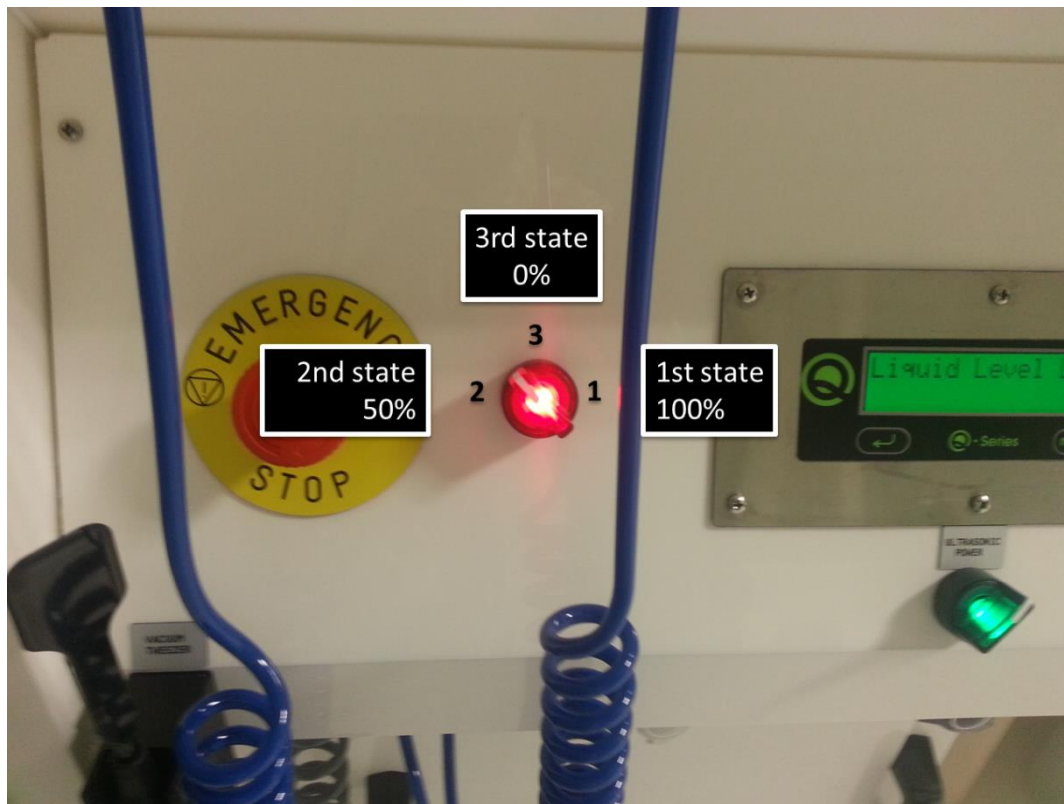


Figure 14. WetBench State adjustment knob

1st state: Air extraction is at full power, and meets the operating conditions. The wet bench is fully operational

2nd state: Air extraction is at half power. Wet bench is left in this state after the operation hours if there is any chemical inside

3rd state: No air extraction over the bench. Only small amount of air is extracted from the chemical storage cabinet under the wet bench.

Care should be taken to ensure that incompatible chemicals are segregated in the wet bench or hood and cannot come into contact.

Designated use wet benches all require users to attend a training session specific to that wet bench. In general there are restrictions on the materials that can be used in designated use wet benches. A list of designated use wet benches and their functions can be found below:

Yellow Room Lithography Wet benches (x2) – The materials used in these wet benches are limited to work involving solvents and mild bases for typical lithographic processing. No strong acids or bases can be used in this hood.

Etch station Wet Benches (x3) – These benches are designated for using strong acids and solutions such as Piranha, HF, wet metal etchants. No large-scale solvent cleans may be used in this hood, only spot cleaning with squirt bottles is allowed.

Personal Protective Equipment

Appropriate Personal Protective Equipment (PPE) must be worn at all times when pouring wet chemicals at a wet bench. If necessary, the PPE may be removed after pouring to enable more dexterous handling of samples. The PPE should not be worn except in the immediate area of the chemical hood. Wearing the PPE around the lab will lead to transferring chemical residues into non-chemical areas of the facility.

For most wet chemicals the following is the full complement of Personal Protective Equipment (PPE) that must be worn when pouring or in cases where a splash is possible.

- **A Face Shield**
- **Chemical Apron,**
- **Thick Chemical Resistant Gloves (over the standard cleanroom gloves).**

6.7.2.1 Chemicals Requiring Only a Face Shield

For some chemicals it is only necessary to wear a face shield when pouring them. For these chemicals it is sufficient to wear the white cleanroom gloves (nitrile) and a full face visor, it is not necessary to wear the thick chemical gloves or an apron. A definitive list of chemicals that require only a face shield is given below. **Chemicals not found in the list require the full complement of personal protective equipment (i.e., face shield, chemical apron, and thick chemical gloves).**

Solvents

- Isopropanol ($[\text{CH}_3]_2\text{CHOH}$)
- Methanol (CH_3OH)
- Acetone ($\text{C}_3\text{H}_6\text{O}$)

Photolithography Chemicals

- AZ5214E IR Photoresist
- AZ 4620 Photoresist
- PMMA A4 Photoresist
- AZ Developer
- AZ 300 MIF Developer
- AZ 400K Developer

If you are working at a wet bench and pouring a chemical that requires the full complement of PPE you must move away from the hood or also be wearing the full complement of PPE.

6.7.2.2 Apron

Chemical aprons have a 'chemical side' that should face out when wearing it. This is to prevent chemical residues from the apron from coming in contact with the wearer.

6.7.2.3 Face Shield

The face shield is to be worn whenever working in or near the hoods. Users should only handle the face shield from the top. Do not handle the face shield by the front as this can contaminate the clear portion of the shield, decreasing visibility. The Nanolab supplies face shields.

6.7.2.4 Chemical Gloves

The most common type of chemical gloves used in the laboratory is nitrile gloves. Users must consider what chemicals they are using and purchase gloves that are resistant. Chemical gloves are to be worn over the standard cleanroom gloves while working in the wet bench. Chemical gloves should not be used to handle items outside the wet bench because the chemical residues can spread to others who are not wearing PPE and they can be injured. Gloves should be rinsed in DI water and dried with a clean wipe after each use.

To prevent contamination, the gloves should be removed whenever handling items outside of the hood such as phones, notebooks, sample holders, keyboards etc. When putting on or removing the

PPE, the nitrile gloves should be the last item put on and the first item removed, to prevent transferring any chemical residues to the face shield or apron straps.

6.7.3 Wet BENCH and Hood Procedures

When preparing to use a wet bench or hood, users should always perform a series of actions to ensure efficient and safe use of the wet bench or the hood. Users should first check that the hood is venting. Then the user should gather together and label all of the necessary chemical containers they intend to use. The user should then put on a chemical apron, face shield, and gloves. Users should make sure there is adequate space. If other users are present, wait until space is adequate. The user can then place the necessary chemical containers in to an appropriate location in the hood. Only then should the user retrieve and pour chemicals.

6.7.3.1 Working with Chemicals

Users should be sure to understand the risks of all the materials they work with in the hoods. The MSDS can be used to understand the properties and hazards of these materials. Here are a few specific things to keep in mind when working in the hoods:

- Use care when pouring chemicals. Transferring chemicals is the most common time for spills and accidents. Funnels should be used whenever necessary to prevent spills.
- Users should plan out their work when they start working in the hood. Users should make certain that they don't need to carry a wafer dripping with chemicals over the length of the hood to get to the sink to rinse it.
- Be sure to take time and be careful with the chemicals. Not only will this help in producing good research, but it will also make the process safer.
- Avoid distractions while working at the hood. Do not take or make phone calls or engage in distracting conversations with other users. Focus on the work that is being performed.

Do not overcrowd the wet bench or the hood by trying to have too many people work at the same time. The current user of the wet bench or the hood may request that others wait until he or she is finished. This should not be used to claim the use of a wet bench or the hood for an excessive period of time though, but should be used to make certain that the work is done safely.

From time to time users may drop a sample into a heat bath contained in a wet bench or fume hood deck. When this occurs users should staff get help to retrieve the sample. Users should never put their

hand, with or without a chemical glove, into a bath to retrieve a sample or wafer cassette even if the bath is cold.

6.7.3.2 Chemical Containers

The labware should be made of compatible material and just large enough to easily work with the samples to be processed. Containers that are too large for a sample will create excessive waste and should not be used. Disposal costs for chemicals are often much more than the original chemical costs, so users should try to minimize wasteful use of the chemicals.

Plastic, Teflon, or glass containers are acceptable for most chemicals. If the solution is to be heated, only a glass container can be used. If using a hydrofluoric acid containing solution, use a plastic or Teflon container. It is advised that all containers have covers on them. Aluminum foil should not be used as a cover for any solutions containing acids or bases.

6.7.3.3 Container Labels

All chemical containers are required to have labels on them that clearly identify the contents. Many solvents and caustics look the same as water, so everything, including water, must be clearly labeled. Rolls of general-purpose cleanroom tape are available throughout the laboratory to label chemical containers. Do not use cleanroom wipes to label containers as the two may become separated.

The label must be clearly printed with the following information;

- Full Chemical Name and Concentration
- User Name
- Date
- Time Started
- Time of Anticipated Finished
- Phone number if you are going to leave the cleanroom

If possible the label should be attached to the chemical container itself and not the container cover or in the hood in front of the chemical. All containers are required to be labeled regardless of whether the user is going to be present the entire time or not. The label should be present on the container before the chemical is poured.

6.7.3.4 24-Hour Rule

Chemicals should not be left in the bench or hood for long periods. Given the number of people in the facility, there is not enough hood space to allow each researcher to have their chemicals left in the hood for more than 24 hours. Chemicals that are to be used frequently over a period of a day may be left for reuse to help reduce the amount of chemical waste generated. By the end of the day however, all chemicals should be disposed of and the container cleaned up.

Chemicals that are hot may be left overnight and allowed to cool, but an extra note indicating this should be placed on the container to show that it was not forgotten about. Substrates are allowed to soak overnight in chemicals if needed, but a note indicating this should be placed on the container, in addition to the standard container label.

Users that are going to leave a chemical container in the hood for later reuse or disposal must place the container toward the back of the hood to make room for others. Chemical containers that are left over 24-hours or left without a label will be disposed of. If there is a sample inside of the container it will be disposed of also.

6.7.3.5 Hot Plates

Hot plates may seem like a simple piece of laboratory equipment, but they can be dangerous if used improperly. There are several dedicated hotplates located in the yellow room used exclusively for baking photoresist. In addition, users are allowed to setup their own hotplates in the general use hoods. It is important that users actively check the material on the hotplate, using a thermocouple to monitor the solution temperature to make certain that the chemical is not heated to a dangerous temperature. This is especially important as the material is being heated up to the operating temperature, as small solution volumes can quickly heat up to a dangerous temperature. In no cases are users allowed to use thermometers containing mercury to check the temperature of a solution.

Only glass containers should be used on hotplates, no matter what temperature the material is being heated to.

Hydrofluoric acid solutions are never to be heated on hotplates in the facility.

Heating flammable solvents on hotplates is highly controlled due to the risk of a fire from the flammable vapors that will be generated. Users must get laboratory management approval for the heating of any flammable solvents.

6.7.3.6 Waste Disposal and Cleanup

Once a user is finished with chemicals in a bench or hood, the chemicals should be disposed of in the appropriate waste bottle or drain. See Section 7 for information on how to dispose of the chemical waste. All chemical containers should be thoroughly rinsed with water. Special rinsing procedures are necessary for any container that held chlorinated solvents (see Section 7). After rinsing, containers should be dried with clean wipes and stored in an appropriate location, not in the hood. The labware should not have any chemical residues or smells. Thoroughly rinse chemical gloves before drying and storing.

When you are finished using a bench or hood do not leave any extra wipes, containers, hotplates, thermocouple readouts, gloves, etc. All items should be returned to their proper places and the hood left clean, dry, and empty for the next user. Drying the bench or hood counter is an important step, as the next user will not know if the drops on the counter are water or a dangerous chemical.

6.7.4 Chemical Handling Rules

Common sense and engineering knowledge is used as a guide. There may be situations not covered by the following rules. Consult with lab management for any situation that is unclear. Do NOT proceed if you have any doubt about the correct procedure.

1. All chemicals must be poured at a working wet bench or fume hood. Do NOT pour chemical if exhaust is inadequate.
2. Chemical-resistant gloves face shields, and aprons must be worn when working with wet chemicals.
3. Only approved chemicals already listed in the MSDS book may be used in the laboratory. Laboratory management must approve new chemicals not already in use in lab. MSDS sheets must be obtained before bringing new chemicals into the lab.
4. MSDS sheets must be read and understood before working with a chemical. All warnings and procedures regarding storage, disposal, etc. must be followed.
5. Chemicals poured in open beakers must remain under a wet bench or fume hood. Do NOT move them out of the wet bench or fume hood.
6. Beakers must be labeled as to chemical name, user name, date and time started, date and time expected to finish, and phone number.
7. Do NOT heat highly flammable liquids such as acetone and alcohol.
8. Turn off hotplates when finished.
9. Use rubber or Nalgene carriers when transporting chemicals through the laboratory. Do NOT carry a bottle without a carrier unless it is directly across from the fume hood being used. Use a plastic cart with containment lip if you are bringing chemicals in from another lab.

10. All chemicals must be stored in clearly marked; sealed containers of a material compatible with the chemical (e.g., do NOT use glass with HF). Markings must include: chemical name, professor and date chemical was brought into lab.
11. Do NOT move or dispose hot chemicals, let them cool first.
12. Chemicals must be stored in the appropriate cabinet except when in actual use.
13. Waste chemicals must be stored in the chemical waste cabinet in clearly marked carboys or waste bottles. Do NOT overfill waste containers. Use funnels where necessary.
14. Chemicals must NOT be stored or left for appreciable amounts of time on the floor or tables and must be labeled as to chemical name and/or strength of mixture.
15. Strongly fuming chemicals such as HCL and Ammonium Hydroxide must be used only in the recessed hot pot areas of the wet bench or fume hood so that lip exhaust helps contain odors.
16. If strong odors are present during chemical processing, stop, turn off hot plate, if on, call lab management and evacuate area. Do NOT continue processing if you smell fumes.
17. It is recommended that you have personal chemical-resistant gloves. Wash gloves in DI water and dry them after each use.
18. Triple rinse empty chemical bottles including cap and affix triple rinse label over chemical name. Date and initial it and place rinsed bottle on the empty bottle rack.
19. Chemical waste must be poured AT THE WET BENCH or FUME HOOD into the appropriately labeled drain or waste bottle. Allow the chemical to cool first and wear safety visor, apron, and special gloves. Wipe down outside of waste bottle with DI water and clean wipe.
20. Use only vented caps (a small hole is visible in the top) or a waste bottle with a pop out plugs in the spout for hydroxide and peroxide solutions.
21. If chemical processing at a wet bench or fume hood needs to continue in your absence, you MUST place the setup towards the back of the hood out of the way and label it (use clean tape) with: your name, chemical(s) used, time and date poured, your phone number, and when you will finish.
22. Report all spills or chemical exposure to lab management.
23. Use appropriate wet bench (e.g., lithography wet bench for solvents, etch stations for acids).
24. Report unsafe conditions or safety violations by others to lab management.

6.8 Hazardous Waste Handling

There are several different types of waste generated in the facility, much of which is hazardous waste that needs special handling. The most common hazardous waste generated by users is chemical waste. Other hazardous waste classes include broken glass, other sharp materials, III-V materials containing arsenic, batteries, etc. Detailed information about SUNUM waste management is given in section 12 of health and safety document.

6.8.1 Chemical Waste

Typically wet benches and fume hoods have acid and solvent drains on them.



Figure 15. Acid and solvent drains on WetBench

Used acids (except HF) can be poured to acid drain by diluting with water and they go the SUNUM neutralization system. Also solvents can be poured to solvent drain that is collected in solvent containers behind the wet benches or fume hoods. HF, piranha and RCA solutions that are used in baths placed on etch stations have separate containers behind the benches. Also photoresists that are used in spinners are drained to photoresist containers at the back of the bench.

6.8.2 Solvent Contaminated Items

Wipes, gloves, or other items that have resists or other spin on polymer solutions on them should not be disposed of in standard trashcans. These polymer solutions will release the solvents into the air. In the lithography room there is a special trashcan next to the spinners that are to be used for disposing of these items.

6.8.3 Sharp Items

Glass, wafers, razor blades, needles, or other sharp materials should not be disposed of in the standard trashcans, as it can cut the plastic trash bags and injure the janitorial staff. The facility has special sharps trashcans for these items. The trashcans are labeled for the disposal of glass waste. Silicon wafers and pieces of wafers should also be disposed in this trash.

6.8.4 Compound Semiconductor Waste

All waste pieces of Gallium Arsenide, Indium Phosphide, and similar compound semiconductors should be deposited into the labeled bins. This is to prevent arsenic contamination of the normal trashcans.

6.9 Emergency Procedures

There are many different types of emergencies that can happen in the laboratory. Although it is not possible to plan ahead for every type of possible emergency, the following sections cover the main types of emergencies that may occur with the appropriate response for each.

6.9.1 Using the Phones to Get Help

To access these emergency services from the regular Micro/NanoFab phones, dial **7555-5555; (0-216-568-7555 ; 0-850-205-7555)** . When calling in an emergency, it is important to clearly communicate the type of emergency to the dispatcher. For medical emergencies you can call **7666-6666; (0-216-568-7666 ; 0-850-205-7666)** directly, it can be helpful to clearly indicate whether the medical emergency is chemically related or not. For example, the emergency response for someone having a heart attack is different than for a person who has a chemical exposure.

Additionally, you can reach SUNUM staff directly by dialing 7474 (0-216-568-7474). Staff members should be contacted for emergencies such as large water leaks, power outages, chemical spills and other serious problems. Also you can call SUNUM security by dialing 7100.

6.9.2 Emergency Response Equipment

Emergency equipment is located throughout the laboratory. Users must familiarize themselves with the location and operation of emergency equipment. Emergency showers and eyewashes are located throughout the facility. There are two First Aid Kits available in the laboratory. Tubes of Calcium Gluconate Gel are available for application on hydrofluoric acid burns. This should be applied promptly, but is not a substitute for medical attention. There are fire extinguishers located in the laboratory.

6.9.3 Chemical Exposures

All chemical exposures require immediate attention. Users, who are exposed to chemicals, must immediately remove all affected clothing as soon as possible to assist in getting the chemical off of the body. Modesty should not prevent users from doing this. Flush the affected areas with water for 15 minutes, not less. Use the emergency shower and/or eyewashes as necessary. Memorize the locations of the safety shower and eyewashes. If exposure occurs while working at a wet bench or fume hood and the exposed area is small the DI water spray can be used to rinse the affected area. Users affected by chemical burns should not worry about any chemical spill, but instead should take care of themselves and allow someone else to deal with the spill. It is a good idea while rinsing the affected area to call for help from another member of the laboratory.

If your eyes are exposed to a chemical while working at a fume hood, if you can do so safely, use the DI water spray to flush your eyes instead of trying to make your way to an eyewash station. Hold your eyes open and flush continuously for 15 minutes. The DI water spray will be your fastest response for such an emergency when working at a fume hood. Exposure of the eyes requires flushing with water for at least 15 minutes. As a precaution, all exposures to the eye will require a visit to an emergency room for a checkup. Contact a staff member as soon as possible for assistance or call 7666-6666; (0-216-568-7666 ; 0-850-205-7666) .

After you have flushed the exposed area with water contact a staff member or have a lab mate contact the staff while you are rinsing the affected area. All chemical exposures occurring in the Nanolab must be reported to the office within 24 hours or on the Monday following a weekend.

HF burns are particularly hazardous. An insidious aspect of HF burns is that there may not be any discomfort until long after exposure. These burns are extremely serious and may result in tissue damage as fluoride ions diffuse through tissue. If you are exposed to HF, flush the area well and be sure to work under and around your fingernails. Under fingernails and cuticles are the main areas people receive burns, having washed off the HF without washing under their nails. Remember, HF may not produce any burning sensation until after it has already done damage. You should have a physician examine all HF burns.

6.9.3.1 First aid for HF Burns to skin

1. Remove contaminated clothing.
2. Flush with cold water for 5 minutes.
3. Get help from other lab members or staff.
4. Gently massage a liberal amount of Calcium Gluconate Gel to the affected area. Calcium Gluconate Gel can be found at the first aid kits as well as on top of most chemical cabinets. Use gloves to avoid secondary exposure of fingers.
5. Report all HF exposures to staff
6. Seek medical attention

6.9.4 Chemical Spills

Users are primarily responsible for cleaning up any minor chemical spill they caused. For large spills users should request assistance from the staff (**7474 (0-216-568-7474)**) and **PRESS EMERGENCY BUTTON** next to the lab door. Detailed information about spills is given in section 3.4 of SUNUM Health and Safety Document.

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6.9.5 Building Alarms

The facility has two types of audible alarms that evacuate the building: fire alarms and toxic gas alarms. For a Fire Alarm, sirens and strobe lights will go off throughout the laboratory. A siren followed by a message that a toxic gas emergency has occurred in the building indicates the toxic gas alarm. The response to both types of alarms is the same: users may take 10 seconds to secure whatever tool they may be working with before evacuating the facility. In addition, all requests from staff to evacuate the facility must be honored immediately. They should then calmly walk to the nearest exit of the facility and meet at the meeting point outside of the building. Researchers in the cleanroom should not return to the gowning room to remove the cleanroom suit, but instead, should exit out the nearest door, and remove the cleanroom suit when they reach safety. Users

should not reenter the building until given the OK by the emergency personnel on the scene. All alarms should be treated as real. Occasional testing of the system is clearly announced throughout the building intercom system. If a user is ever in doubt about whether an alarm is real or not, they should proceed to evacuate, and then determine if the event was real once they have left the area. In the event of an explosion, large fire, or other circumstance that requires the entire building to be evacuated, toxic gases to be shut off, and police and fire departments to be summoned, users should press one of the emergency evacuation buttons located in the facility. The exact location of the buttons will be shown during the walkthrough.

6.9.6 Fire

The Nanolab has three fire extinguishers located inside the laboratory. If a fire is discovered, alert other laboratory users and personnel and stand clear to assess the situation. Do NOT attempt to fight fires larger than "waste basket" size or fires obviously out of control. If you are not comfortable fighting the fire yourself, activate a fire alarm and evacuate the building. Detailed information of fire response can be found in section 3.3 of SUNUM Health and Safety Document.

6.9.7 Earthquakes

If you are in the cleanroom during an earthquake, duck under the nearest sturdy object and hold onto it until the shaking stops. If you are not near a sturdy object, make yourself as small as possible and cover your head and neck. If you stand in a doorway, brace yourself against the frame and watch out for a swinging door or other obstructions.

Avoid windows, fume hoods, wet benches, chemical cabinets, process equipment, storage cabinets, and other heavy or dangerous objects that could fall or shatter. Stay under cover until the shaking stops, and then evacuate the building. If safe, before evacuating, stabilize any laboratory procedure that could lead to further danger. Do not reenter the building until you receive definite information from the laboratory management that the building is safe.

6.9.8 Incident Reporting

In addition to normal emergency response, all accidents involving chemicals and all accidents involving personal injury must be reported to the Micro/NanoFab management in writing as soon as possible after the incident. Explanations should include the nature of the event, the procedures being followed or not followed at the time, and actions required to prevent future similar incidents. In addition, for cases involving personal injury to employees, the university may require additional documentation.

7 ELECTRICAL SAFETY

Electrically powered equipment, such as hot plates, stirrers, vacuum pumps, electrophoresis apparatus, lasers, heating mantles, ultrasonicators, power supplies, and microwave ovens are essential elements of many laboratories. These devices can pose a significant hazard to laboratory workers, particularly when mishandled or not maintained. Many laboratory electrical devices have high voltage or high power requirements, carrying even more risk. Large capacitors found in many laser flash lamps and other systems are capable of storing lethal amounts of electrical energy and pose a serious danger even if the power source has been disconnected.

7.1 ELECTRICAL HAZARDS

The major hazards associated with electricity are electrical shock and fire. Electrical shock occurs when the body becomes part of the electric circuit, either when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor.

The severity and effects of an electrical shock depend on a number of factors, such as the pathway through the body, the amount of current, the length of time of the exposure, and whether the skin is

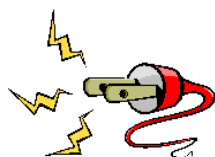


Figure 16

wet or dry. Water is a great conductor of electricity, allowing current to flow more easily in wet conditions and through wet skin. The effect of the shock may range from a slight tingle to severe burns to cardiac arrest. The chart below shows the general relationship between the degree of injury and amount of current for a 60-cycle hand-to-foot path of one second's duration of shock.

While reading this chart, keep in mind that most electrical circuits can provide, under normal conditions, up to 20,000 milliamperes of current flow

Current	Reaction
1 Milliampere	Perception level
5 Milliamperes	Slight shock felt; not painful but disturbing
6-30 Milliamperes	Painful shock; "let-go" range
50-150 Milliamperes	Extreme pain, respiratory arrest, severe muscular contraction
1000-4,300 Milliamperes	Ventricular fibrillation
10,000+ Milliamperes	Cardiac arrest, severe burns and probable death

In addition to the electrical shock hazards, sparks from electrical equipment can serve as an ignition source for flammable or explosive vapors or combustible materials.

Power Loss

Loss of electrical power can create hazardous situations. Flammable or toxic vapors may be released during the heating of a chemical or when a refrigerator or freezer fails. Fume hoods may cease to operate, allowing vapors to be released into the laboratory. If magnetic or mechanical stirrers fail to operate, safe mixing of reagents may be compromised.

7.2 PREVENTING ELECTRICAL HAZARDS

There are various ways of protecting people from the hazards caused by electricity, including insulation, guarding, grounding, and electrical protective devices. Laboratory workers can significantly reduce electrical hazards by following some basic precautions:

- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
- Use safe work practices every time electrical equipment is used.
- Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
- Limit the use of extension cords. Use only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
- Multi-plug adapters must have circuit breakers or fuses.
- Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
- Minimize the potential for water or chemical spills on or near electrical equipment.

7.2.1 Insulation

- All electrical cords should have sufficient insulation to prevent direct contact with wires. In a laboratory, it is particularly important to check all cords before each use, since corrosive chemicals or solvents may erode the insulation.
- Damaged cords should be repaired or taken out of service immediately, especially in wet environments such as cold rooms and near water baths.

7.2.2 Guarding

Live parts of electric equipment operating at 50 volts or more (i.e., electrophoresis devices) must be guarded against accidental contact. Plexiglas shields may be used to protect against exposed live parts.

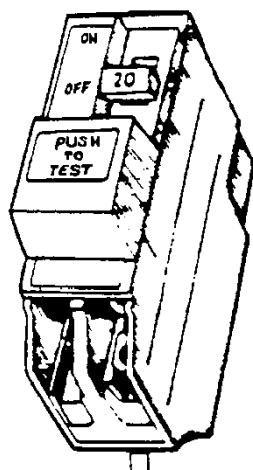
7.2.3 Grounding



Only equipment with three-prong plugs should be used in the laboratory. The third prong provides a path to ground for internal electrical short circuits, thereby protecting the user from a potential electrical shock.

Figure 17 Three-prong plugs

7.2.4 Circuit Protection Devices



Circuit protection devices are designed to automatically limit or shut off the flow of electricity in the event of a ground-fault, overload or short circuit in the wiring system. Ground-fault circuit interrupters, circuit breakers and fuses are three well-known examples of such devices.[Figure 18]

Fuses and circuit breakers prevent over-heating of wires and components that might otherwise create fire hazards. They disconnect the circuit when it becomes overloaded. This overload protection is very useful for equipment that is left on for extended periods of time, such as stirrers, vacuum pumps, drying ovens, Variacs and other electrical equipment.

Figure 18 Circuit Protection Devices

The ground-fault circuit interrupter, or GFCI, is designed to shutoff electric power if a ground fault is detected, protecting the user from a potential electrical shock. The GFCI is particularly useful near sinks and wet locations. Since GFCIs can cause equipment to shutdown unexpectedly, they may not be appropriate for certain apparatus. Portable GFCI adapters (available in most safety supply catalogs) may be used with a non-GFCI outlet.

7.2.5 Motors

In laboratories where volatile flammable materials are used, motor-driven electrical equipment should be equipped with non-sparking induction motors or air motors. These motors must meet National Electric Safety Code (US DOC, 1993) Class 1, Division 2, Group C-D explosion resistance specifications. Many stirrers, Variacs, outlet strips, ovens, heat tape, hot plates and heat guns **do not** conform to these code requirements.

Avoid series-wound motors, such as those generally found in some vacuum pumps, rotary evaporators and stirrers. Series-wound motors are also usually found in household appliances such as blenders, mixers, vacuum cleaners and power drills. These appliances should not be used unless flammable vapors are adequately controlled.

Although some newer equipment have spark-free induction motors, the on-off switches and speed controls may be able to produce a spark when they are adjusted because they have exposed contacts. One solution is to remove any switches located on the device and insert a switch on the cord near the plug end.

7.3 SAFE WORK PRACTICES

The following practices may reduce risk of injury or fire when working with electrical equipment:

- Avoid contact with energized electrical circuits.
- Use guarding around exposed circuits and sources of live electricity.
- Disconnect the power source before servicing or repairing electrical equipment.
- When it is necessary to handle equipment that is plugged in, be sure hands are dry and, when possible, wear nonconductive gloves and shoes with insulated soles.
- If it is safe to do so, work with only one hand, keeping the other hand at your side or in your pocket, away from all conductive material. This precaution reduces the likelihood of accidents that result in current passing through the chest cavity.
- Minimize the use of electrical equipment in cold rooms or other areas where condensation is likely. If equipment must be used in such areas, mount the equipment on a wall or vertical panel.
- If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment.

- If an individual comes in contact with a live electrical conductor, do not touch the equipment, cord or person. Disconnect the power source from the circuit breaker or pull out the plug using a leather belt.
- It is good practise to label all plugs with the equipment they feed, as this helps disconnect in an emergency and also prevents accidental disconnection.
- In the event of a person suffering an electric shock: switch off the supply, and move the victim out of contact with the live equipment, taking care to use an insulating object or material so that you do not risk the same shock yourself. If the victim is unconscious, call a first aider to begin artificial respiration. Then call the emergency services.

7.4 HIGH VOLTAGE OR CURRENT

Repairs of high voltage or high current equipment should be performed only by trained electricians. Laboratory workers who are experienced in such tasks and would like to perform such work on their own laboratory equipment must first receive specialized electrical safety related work practices training by SUNUM staff. Contact SUNUM Lab Supervisors for more information.

7.5 ALTERING BUILDING WIRING AND UTILITIES

Any modifications to existing electrical service in a laboratory or building must be completed or approved by either the building facility manager, an engineer from the Facilities department or the building's Special Facilities staff. All modifications must meet both safety standards and Facilities Engineering design requirements.

Any unapproved laboratory facilities modifications discovered during laboratory surveys or other activities are reviewed by Lab supervisors and facility staff to determine whether they meet design specifications.

8 MECHANICAL SAFETY

Under no circumstances are machines or tools in a workshop to be used by persons other than those skilled tradespersons employed in the workshop - or persons who have been properly trained prior, and are authorized by the Head of Department. A minimum of two people must be in the workshop when operating heavy machinery.

8.1 WORKSHOP SAFETY

Most workshop machinery is fitted with a safety device and this must not be removed except under the direct supervision of the Head of the Workshop. It is the operators responsibility to ensure that all safety equipment is in position before using machinery. If equipment becomes defective during operation, the machine must be shut down and reported to the Head of the workshop. When changing tools, the machine must always be stationary.

- All workshops should be maintained in a clean and tidy condition and all workshop users should assist by replacing tools and equipment immediately after use and by removing e.g. swarf and filings as soon as possible.
- Tools are not to be "stored" on machine beds while the machine is running.
- Nothing should be stored on the floor where a tripping hazard may be created and any spillages must be cleaned up immediately. Metal waste bins are provided for swarf and scrap.
- All situations that might cause an accident must be reported e.g. breakage on tools and machinery, faulty wiring, worn or defective equipment and unsatisfactory storage arrangements.
- Accidents or potential accidents must be reported to Lab Supervisors.
- Personal safety equipment e.g. all eye, ear, breathing, clothing, gloves provided must be used when applicable.
- Proper racking facilities are provided for storage of sheet materials, rods, and bars. Vertical racking can be dangerous unless a safety chain or bar is used, and in horizontal racking the chance of accidental contact with the protruding end of rods and the sharp corners of sheet materials should be minimized.
- Hand tools may cause injury unless kept in good condition, used properly and stored safely and tidily. The correct tool should always be used for the job. Hammer heads should be regularly inspected for flaws and should be firmly attached to their shafts and the heads of

cold chisels and punches must either be ground down or replaced - mushroom heads are very dangerous.

- Portable electrical equipment (e.g. drills) must be regularly inspected visually, and electrically tested in accordance with Electrical Code of Practice. Loose cables should be kept off the floor as far as possible and certainly out of the circulation areas. Portable appliances should be disconnected when not in use, and machinery must be switched off when not in use.
- Compressed air must never be used for blowing dust or swarf off clothing, skin or machinery. Wrongly used compressed air can cause embolism, blindness or deafness to personnel and damage to nearby machinery.
- All personnel that will use the machine tools must either take a class in Machine Tool Operation or, through their prior experience, be able to prove their proficiency to the Shop Instructor.
- The area directly surrounding the Machine Tools must be marked off (yellow floor tape or paint).
- All personnel in the shop area must wear eye protection at all times.
- Hearing protection (ear plugs) should be readily available to shop users
- A first aid kit must be placed in the shop, and a lab member should be assigned to keep it well stocked.
- An oil spill kit should be purchased and placed in an accessible spot with an assigned lab responsible for its contents.
- A fire extinguisher must be readily available.
- Basic Safety rules must be followed at all times. Among these are:
- Long hair must be tied back at all times
- No sandals or opened toed shoes are permitted in the work area
- If lifting heavy objects you are required to wear steel toe safety shoes
- Any oil spilled on the floor must be immediately cleaned up
- Loose fitting clothing must be tucked in or tied up
- Neckties must be removed
- Bracelets and other loose jewellery must be removed prior to using the shop.
- No horseplay around the machines is permitted. Machine tools can be dangerous.
- No person should work alone. In certain situations people may establish a buddy system where people located in other parts of the building are responsible for checking to see that the shop user is safe at all times. A possible implementation might involve the purchase a good set of two-way radios. The “buddy” could then call the user every 15 minutes or so to check on his safety. If the “buddy” does not get a response, he/she would then immediately go to the shop area to check on the shop user. As part of this system, a sign-in sheet could

be placed in the shop that the users would fill in to indicate when they entered and left the area, and name and location of their buddy.

- The shop area must be kept clean. It is impossible to maintain a safe work environment if tools, stock and last week's coffee are lying about the equipment. A lab member should be put in charge of the shops cleanliness.
- Practice common sense. If your gut tells you not to setup a part in a certain way in a machine, don't do it. Most shop accidents are a result of lack of knowledge, not carelessness. If you have any doubt, consult the professional machinist (Stan Cotreau in the physics machine shop).

8.2 MAINTENANCE

Maintenance of the machine tools is key to safe operation. Each week a lab member should be elected to lubricate the equipment. If the proper lubrication regimen is not known, consult Lab Supervisors. They will gladly to instruct you as to what needs to be done.

Cutting tools, such as drill bits, end mills, and lathe turning tools should be inspected and sharpened as required on a weekly basis. A sheet should be placed in the shop so the shop users record which drills, tool bits, end mills, etc. are either broken or in need of sharpening or repair.

Milling machines should have the alignment checked on a monthly basis. The machinery must be cleaned after each usage. Dirty machine tools tend to need repair and alignment more frequently than clean ones. It is the responsibility of the shop user to clean up after himself/herself. Chips and debris must be swept up and properly disposed. One must clean the machine tools so they are in the same condition as when one began to work. All hand and measuring tools must be returned to their proper storage site. All unused stock must be placed back in proper storage. If your lab has a belt driven milling machine the belt should be inspected for wear every month.

Measuring tools should be kept in good working order. They should be stored in a clean space, away from the chips and oil of the cutting environment. Measuring tools should have their "zero" checked prior to each use.

A machine shop is, by nature, a dangerous place. All machinery has the potential to cause you harm if it is used incorrectly or not inspected periodically. Please remember that it is always a bad idea to run dangerous equipment if you are over tired or not feeling well. Never operate the equipment if

you are under the influence of alcohol or cold medication that makes you drowsy. Focus is very important.

Accidents in the shop happen very quickly and most always there isn't any warning before a problem occurs. The shop guidelines listed above, if put into use, will allow one to work safely and independently in a small machine shop. Remember, above all else it is important to work safely!

8.3 SAFETY IN THE OPERATION OF ROBOTS

- 1) Always follow the exact sequence of operation for power-up and power- down.
- 2) Always start arm motions at slow speed. Only when arm paths are fully defined and verified, then the speed may be increased.
- 3) Always be aware of obstacles on the arm paths, and the limits of its working range.
- 4) Never enter the working range of the arm during its operations, or when someone is programming it with the controller.
- 5) Never press "Arm Power Off" button while the robot is moving, except for emergency stop purposes.
- 6) Do not replace components or make adjustments to the interior of the robot while the electrical supply is still switched on.
- 7) Cables to any connection port must never be inserted or removed unless the power has been switched off from the robot.
- 8) When on manual free mode, make sure that when the appropriate joint switch is pressed, the arm is properly supported and prevented from free- swinging.

9 RADIATION / LASER SAFETY

9.1 X-RAY RADIATION SAFETY

X-rays are the expression of “extra” electromagnetic energy emitted as the result of the change in energy state or momentum of an electron near the nucleus of an atom. X-rays consist of high-energy waves that can travel great distances at the speed of light and generally have a great ability to penetrate other materials. Their wavelengths range from 10^{-12} m to 10^{-8} m on the Electromagnetic Spectrum.

X-rays are produced when a high-voltage source is used to accelerate electrons through a target material. The penetrating ability of the x-rays produced is dependent on their energy.

Soft x-rays: generally fall into the range of 10^{-8} to 10^{-10} meters on the electromagnetic spectrum and have energies ranging from less than 1 keV to about 10 keV.

Hard x-rays generally fall into the range of 10^{-10} to 10^{-12} meters on the electromagnetic spectrum and have energies ranging from about 10 keV to 120 keV.

Only a small percentage of the energy carried by the electrons is converted to x-rays upon striking the target. Typically, greater than 99 percent of the energy will be converted to heat and absorbed by the target. The target is usually cooled with water or oil to prevent it from melting and rotates to avoid constant exposure to the same area.

X-Ray radiation is a form of ionization radiation that is potentially very hazardous. The most intense and therefore dangerous part of the instrument is the path of the incident X-ray beam. Thus care should always be exercised to know the expected path of the incident beam. Scattered radiation is typically of such reduced intensity that it poses a much smaller health risk to the researcher. They present a hazard for external exposure. Depending on the energy of the x-rays, damage may occur to the skin by absorption of the x-rays (low energy) or to vital organs due to penetration of the X-rays deeper into the body (high energy). X-ray radiation is considered to be a form of ionizing radiation. X-rays will pass through the body, causing ionization and indirect damage. When an x-ray strikes the body, it is mainly affecting water (since our bodies are 70% water). Most damage to intracellular molecules is done by an indirect process. When an x-ray interacts with a water molecule, free radicals are produced, which may cause cellular death. Changes in cellular material or DNA damage may also occur by direct interaction of the ionizing radiation with DNA or other

important intracellular molecules. They can be blocked by several feet of concrete or a few inches of dense material (such as lead).

There are several properties of X-rays that make this type of radiation particularly dangerous to use in the laboratory. X-Ray radiation cannot be sensed by a human! Some people feel a tingling sensation on their skin when they are around X rays from an analytical instrument. They are not feeling the X-ray beams, but rather they are feeling charged air particles produced by the interaction of the ionizing X rays with air. If you ever feel a tingling sensation when working around any analytical X ray instrument, immediately turn off the instrument and contact the SUNUM admin. Since only some people feel this tingling sensation, do not assume that if the sensation is not present, that the instrument cannot hurt you.

X-ray machines are just machines. When the power is turned off (i.e. no current or voltage), that machine no longer produces radiation. Therefore, there is no danger present from an x-ray machine when the unit is powered down.

When older instruments were tested for radiation leaks, it was occasionally found that potentially dangerous beams were coming from the instrument in very unexpected directions. The X-ray beams appeared to bounce off surfaces of the instrument and to bend around corners.

Thus, it is important to be careful when using an X-ray instrument. Never put any part of your body in the expected path of the main beam. Avoid being around the X ray tube housing and main beam path as much as possible. Keep the enclosure doors closed whenever possible.

Generally, the types of radiation used in diffraction instruments (primarily Mo and Cu $K\alpha$ radiation) are considered soft or low energy radiation. Unlike medical X rays,

these types of soft radiation generally will not penetrate more than 2-4 cm into the body.

9.1.1 Possible Health Effects

Health effects of exposure to X-ray radiation come in two general types, direct or indirect. X Rays are thought to create radicals in exposed cells of your body that may break or modify chemical bonds within critical biological molecules. As a result (1) cells may be injured or damaged,

although many cells repair themselves, resulting in no residual damage, (2) cells may die, which millions of body cells do every day and are replaced in a normal biological process, (3) or cells may incorrectly repair themselves resulting in a biophysical change. Finally, X rays may pass through the body with no interaction.

Factors that determine biological effects:

- Dose rate
- Total dose received
- Energy of the radiation
- Area of the body exposed
- Individual sensitivity
- Cell sensitivity

Most sensitive: Blood-forming organs, reproductive organs, digestive organs

Least sensitive: Nervous system, muscle and connective tissues

Injuries experienced as a result of radiation exposure include the following:

- Radiation burns from acute exposures
- Radiation sickness from both acute and chronic exposures
- Long-term effects from acute and chronic exposures

Acute exposures

- One time event
- High-level doses involved (>100 rem)
- Effects appear quickly (within days to weeks)

Chronic exposures

- Long-term
- Low-level doses involved
- Effects will appear slowly because the body has time to heal itself after exposure. The effects, if any, will appear 20-30 years after exposure.

Radiation Burns; occur as a result of an acute localized exposure. Radiation burns can occur from a wide range of exposures and usually result from a direct exposure to the primary beam. The hands, fingers and eyes are the parts of the body most commonly at risk. The severity of the burn will depend on the dose received, the length of the exposure, the energy of the x-rays and the sensitivity of the individual. Burns can be caused with exposures of 300 rem, but normally do not become apparent below exposures of at least 600 rem.

Radiation Sickness; occurs when a large dose is received to the whole-body. Symptoms usually will not start to appear unless the exposure is greater than 100 rem delivered within a few hours. Blood changes can occur at exposures as low as 25 rem. If a whole-body dose of 400-500 rem is received, approximately 50% of those exposed will die within 30 days if untreated. Recovery is likely with medical care although the exposed individual will suffer several months of illness. Exposure to a dose in excess of 700 rem to the entire body in a short period of time will likely result in death within a few weeks. If the radiation dose is spread over several weeks, a person may survive a whole-body dose as large as 1000 to 2000 rem. Figure 19

Acute Whole-Body Exposure	
Symptom	Dose (rem)
Blood Cell Changes	25-50
Nausea, Diarrhea	100
Hair Loss	250
Erythema	300
Sterility/Death (LD _{50/30} *) - no treatment	450 - 500
↓ No Recovery Expected (LD ₁₀₀ **) ↓	
Gastrointestinal Syndrome	1000
Central Nervous System Syndrome	>2000

* The dose of radiation expected to cause death to 50 percent of an exposed population within 30 days
 ** The dose of radiation expected to cause death to 100 percent of an exposed population

Figure 19 Radiation Dose

X rays are a form of ionizing radiation and are capable of displacing tightly bound electrons from their orbits, causing atoms to become charged. Because X rays penetrate and cause damage to tissues, they pose a health hazard.

A modern X-ray diffraction system is not hazardous if it is used correctly. Safety devices are built into the instrument that makes it very difficult for anyone to be exposed to the X-ray beam. Despite safety devices, it is important to be careful when using the instrument. Never put any part of the body in the expected path of the X-ray beam.

To help ensure their safety, users of the X-ray diffraction system **MUST** be familiar with pertinent radiation safety considerations, **MUST** follow normal operating procedures that minimize the potential for accidental exposure to X rays, and **MUST** know what to do in the event of accidental exposure.

Somatic, genetic, and teratogenic effects

Somatic effects of radiation occur in the individual that received the dose. If offspring of the irradiated individual are effected, such effects are referred to as genetic or teratogenic. Genetic effects in an offspring are due to radiation received by the parent prior to conception and are caused by radiation-induced genetic aberrations in the parent. Teratogenic effects in an offspring are due to radiation received by the parent, effectively the fetus, during the gestation period. (See special note to pregnant women.)

Stochastic effects

Stochastic effects of radiation are not directly related to the dose received. Stochastic effects involve chance or probability. Some forms of melanoma, for example, may occur as a stochastic effect of exposure to radiation from the sun. The conservative perspective on stochastic effects assumes no minimum threshold and that any amount of exposure may cause the effect.

Nonstochastic effects

Nonstochastic effects are directly related to the dose received. Such effects typically have a threshold, below which the effect does not occur and above which the effect is more severe with higher doses. A skin burn due to radiation is a nonstochastic effect. Most of us have experienced a nonstochastic effect of high doses of solar radiation, the common sunburn. The goal of radiation safety is to eliminate non-stochastic effects and to reduce the incidence of stochastic effects.

Protection of X-ray Beams

Among the most important aspects of an x-ray safety are the attitudes and actions of the individual users. Taking personal responsibility for one's own safety can have a tremendous impact on the safety of the lab as a whole. In the case of any X-Ray injury please inform the laboratory supervisor or administrator first and report all injuries to 7666-6666; (0-216-568-7666 ; 0-850-205-7666) .

9.2 RADIATION SAFETY REQUIREMENTS FOR USE OF ELECTRON MICROSCOPES

Source of Radiation from an Electron Microscope

X-rays are produced in the electron microscope whenever the primary electron beam or back scattered electrons strike metal parts with sufficient energy to excite continuous and/or characteristic X-radiation. In terms of X-ray hazards, two aspects are important: the composition of the parts which are struck and their efficiency as X-ray sources and the effectiveness/integrity of the shielding provided by the metal casing of the microscope around these.

The higher the voltage and atomic number of the "parts", the greater the efficiency of X-ray production.

The degree of X-ray "**leakage**" also depends on the shielding provided by the metal casing. A poorly designed microscope may have weak points where X-rays can escape, for example, between the gasket sealed junction of two sections of the column.

9.2.1 What are the radiation safety concerns?

The radiation safety concerns are related to the **electrons that are backscattered** from the sample, as well as **X-rays produced** in the process. Most modern electron microscopes are extremely well shielded and do not produce exposure rates greater than background. However, electron microscopes are radiation-generating devices and should be at least inventoried. It is also important that the integrity of the shielding is maintained, that all existing interlocks are functioning, and that workers are aware of radiation safety considerations.

9.3 LASER SAFETY

LASER is an acronym which stands for Light Amplification by Stimulated Emission of Radiation. The laser produces an intense, highly directional beam of light. The most common cause of laser-induced tissue damage is thermal in nature, where the tissue proteins are denatured due to the temperature rise following absorption of laser energy.

The human body is vulnerable to the output of certain lasers, and under certain circumstances, exposure can result in damage to the eye and skin. Research relating to injury thresholds of the eye and skin has been carried out in order to understand the biological hazards of laser radiation. It is now widely accepted that the human eye is almost always more vulnerable to injury than human skin.

Lasers have been classified by wavelength and maximum output power into four classes and a few subclasses since the early 1970s. The classifications categorize lasers according to their ability to produce damage in exposed people, from class 1 (no hazard during normal use) to class 4 (severe hazard for eyes and skin):

Class 1 Laser is safe under all conditions of normal use. This means the maximum permissible exposure (MPE) cannot be exceeded when viewing a laser with the naked eye or with the aid of typical magnifying optics (e.g. telescope or microscope).

Class 1M Laser is safe for all conditions of use except when passed through magnifying optics such as microscopes and telescopes. Class 1M lasers produce large-diameter beams, or beams that are divergent. The MPE for a Class 1M laser cannot normally be exceeded unless focusing or imaging optics are used to narrow the beam.

Class 2 Laser is safe because the blink reflex will limit the exposure to no more than 0.25 seconds. It only applies to visible-light lasers (400–700 nm). Class-2 lasers are limited to 1 mW continuous wave, or more if the emission time is less than 0.25 seconds or if the light is not spatially coherent. Intentional suppression of the blink reflex could lead to eye injury. Many laser pointers and measuring instruments are class 2.

A Class 2M Laser is safe because of the blink reflex if not viewed through optical instruments. As with class 1M, this applies to laser beams with a large diameter or large divergence, for which the amount of light passing through the pupil cannot exceed the limits for class 2.

Class 3R Laser is considered safe if handled carefully, with restricted beam viewing. With a class 3R laser, the MPE can be exceeded, but with a low risk of injury. Visible continuous lasers in Class 3R are limited to 5 mW. For other wavelengths and for pulsed lasers, other limits apply.

Class 3B Laser is hazardous if the eye is exposed directly, but diffuse reflections such as those from paper or other matte surfaces are not harmful. The AEL for continuous lasers in the wavelength range from 315 nm to far infrared is 0.5 W. For pulsed lasers between 400 and 700 nm, the AEL is 30 mW. Other limits apply to other wavelengths and to ultrashort pulsed lasers. Protective eyewear is typically required where direct viewing of a class 3B laser beam may occur. Class-3B lasers must be equipped with a key switch and a safety interlock. Class 3B lasers are used inside CD and DVD writers, although the writer unit itself is class 1 because the laser light cannot leave the unit.

Class 4 is the highest and most dangerous class of laser, including all lasers that exceed the Class 3B AEL. By definition, a class 4 laser can burn the skin, or cause devastating and permanent eye damage as a result of direct, diffuse or indirect beam viewing. These lasers may ignite combustible materials, and thus may represent a fire risk. These hazards may also apply to indirect or non-specular reflections of the beam, even from apparently matte surfaces—meaning that great care must be taken to control the beam path. In most states it is illegal to sell preassembled class 4 lasers, however a citizen can construct a class 4 laser for personal use. Class 4 lasers must be equipped with a key switch and a safety interlock. Most industrial, scientific, military, and medical lasers are in this category.

Different structures of the eye can be damaged from laser light depending on the wavelength. Retinal burns, resulting in partial or complete blindness are possible in the visible (400 - 700 nm) and near-infrared (700 - 1400 nm) regions. At these wavelengths, the eye will focus the beam or a specular reflection on a tiny spot on the retina. This focusing increases the irradiance of the beam by a factor of about 100,000. Laser emissions in the ultraviolet (< 400 nm) and far-infrared (> 1400 nm) regions are primarily absorbed by and cause damage to the cornea. In the near-ultraviolet range (315 - 400 nm), some of the radiation reaches the lens of the eye.

Skin damage can occur from exposure to infrared or ultraviolet light. For infrared exposure, the results can be thermal burns or excessively dry skin depending on the intensity of the radiation. In the 230 - 380 nm range of ultraviolet light, erythema (sunburn), skin cancer, or accelerated skin aging are possible. The most damaging region of ultraviolet is 280 - 315 nm, also known as UV-B.

ELECTRICAL Many lasers contain high-voltage components which can present a potentially lethal hazard.

Except for fully enclosed and interlocked systems, an authorized user must be present or the room kept locked during laser operations.

Eye protection designed for the specific wavelength of laser light should be available and worn when there is a chance that the beam or a hazardous reflection could reach the eye.

Protective eye wear should be marked by the manufacturer with the wavelength range over which protection is afforded and the minimum optical density within that range. Eye wear should be examined prior to each use and discarded if there is damage which could reduce its effectiveness.

Wavelength range	Pathological effect
180–315 nm (UV-B, UV-C)	photokeratitis (inflammation of the cornea, equivalent to sunburn)
315–400 nm (UV-A)	photochemical cataract (clouding of the eye lens)
400–780 nm (visible)	photochemical damage to the retina, retinal burn
780–1400 nm (near-IR)	cataract, retinal burn
1.4–3.0µm (IR)	aqueous flare (protein in the aqueous humour), cataract, corneal burn
3.0 µm–1 mm	corneal burn

Remove unnecessary reflective items from the vicinity of the beam path. Do not wear reflective jewellery such as rings or watches while working near the beam path. Be aware that lenses and other optical devices may reflect a portion of the beam from their front or rear surfaces. Avoid placing the unprotected eye along or near the beam axis. The probability of a hazardous specular reflection is greatest in this area.

EMERGENCIES OR INCIDENTS

In the event of an accident or unusual incident involving a laser:

1. TURN OFF THE LASER.
2. If there is a serious injury or fire, call **7555-5555; (0-216-568-7555 ; 0-850-205-7555)** and request paramedics or the fire department.
3. Notify the Laboratory Supervisors (**7474 (0-216-568-7474)**). If after working hours, call **7555-5555; (0-216-568-7555 ; 0-850-205-7555)** and contact a Safety Officer.
4. Notify the laboratory supervisor or administrator.

5. Report all injuries to the **7666-6666; (0-216-568-7666 ; 0-850-205-7666) .**

9.4 ULTRAVIOLET LIGHT

The risk to health from artificial sources of UV light can be much higher than those from naturally occurring UV. Typically, levels of UV from artificial sources may be many times higher than that of the sun, and may include harmful wavelengths that are normally filtered out by the atmosphere. A powerful source of UV light may be invisible to the naked eye, or emit only a dim light. This is because the cells in the eye which are responsible for vision have a limited response to UV.

Brightness is therefore no indication of power.

Exposure to all types of UV is associated with long-term effects such as skin cancer and immune suppression. UV-B and UV-C are also known mutagens.

It is vital to have in place appropriate control measures to limit exposure to eyes and skin and to prevent cumulative exposure. The precautions needed will depend upon the risk assessment may include the following:

- Sources should be fitted with enclosures or partial shielding to provide protection.
- Take care not to exposure others-ensure your work area is adequate screened.
- Use appropriate UV absorbing, full-face shield, gloves and a lab coat that fastens securely at the wrists and the neck.

If you are particularly sensitive to UV, It is advisable to avoid exposure altogether.

10 SUPERCONDUCTING MAGNET SAFETY

Many cryogenic systems include superconducting magnets which operate at very high fields.

Extensive studies continue into the direct effect of magnetic fields on the health (especially in relation to clinical MRI, where patients are necessarily exposed to very high fields for diagnostic imaging) and the current recommendations are summarized in sections 4.4 and 4.5

Far more hazardous are the indirect effects on stray ferromagnetic objects (including everyday items such as hand tools, keys and coins) and instrumentation and the results of a magnet quench (section 4.6)

Consider the following hazards (at least)

- Magnetic items may move suddenly and uncontrollably towards a magnet; an example graph showing the sudden increase of force at a particular distance is given in Figure below. Most tools are magnetic.
- Someone could be trapped between a large magnetic item (such as a gas cylinder) and a cryostat, resulting in severe injury or death.
- Medical electronic implants (such as pacemakers) may be affected by a magnetic field.
- The magnetic field is three dimensional so the field may affect rooms on the floors above and below your laboratory, as well as on the same floor [Figure 21]
- Magnets may suddenly quench and release their stored energy into the liquid helium (see section 4.6)
- Remember all the potential cryogenic hazards summarized in section 10.
- Magnetic data on the credit cards, disks, and other magnetic storage media may be corrupted.

Every magnet site should be reviewed individually to determine precautions to be taken against these hazards. Figure 20Figure 19

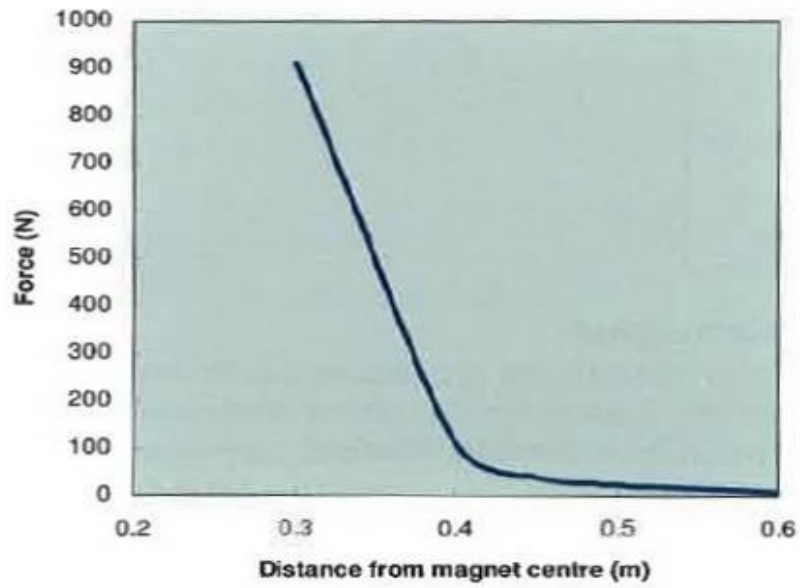


Figure 20 Example showing the force experienced by a 200gr mild steel object as it approaches a large superconducting solenoid.

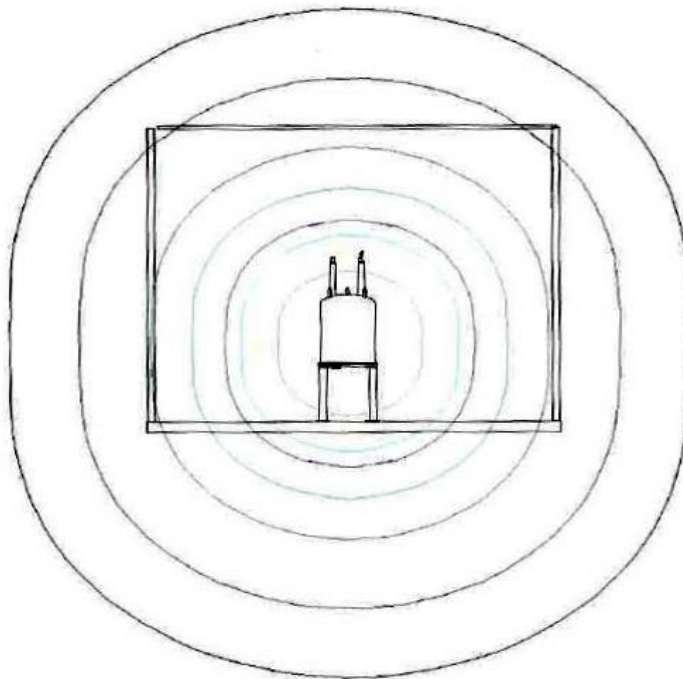


Figure 21 The field is 3-dimensional and affects areas on floors above and below the laboratory.

10.1 BEFORE ENERGISING THE MAGNET

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Before you start to energize the magnet:

- Ensure that all loose ferromagnetic objects are secured or moved to a safe distance. These will normally be safe outside the 5 gauss field contour.
- Check that the protection circuit is connected. Oxford Instrument magnets fitted with persistent switches are impossible to energize unless condition is satisfied.
- Connect one ground wire between the earth points on the cryostat and the power supply and a second wire between the same cryostat earth and laboratory earth point.
- Check that there is an insulating rubber cover fitted over the current lead terminals.
- Display warning signs (preferably illuminated) at all laboratory doors, to remind people that the magnet is operating.
- Display warning signs notice of the possible presence of magnetic field and of the potential hazards in all areas where the field may exceed 5 gauss.
- Ensure that all electronics and interfacing equipment's are removed to areas where the field level is sufficiently low.
- Assess the safe working field level of all other equipment and take appropriate action.
- Check that the helium reservoir is protected by suitable pressure relief valves in the case of magnetic quenches.
- Consider carefully whether the exhaust gas or gas released by a pressure relief valve in the events of a quench could injure someone working on the system.
- Check that there is enough liquid helium in the system.

10.2 WHILE THE MAGNET IS AT FIELD

While the magnet is at field make the following checks regularly:

- Check the liquid helium and liquid nitrogen levels and refill if necessarily.
- Check the boiloff rated of helium and nitrogen gas are normal
- Check the warning signs are still in place: Restrict access to unauthorized personnel.
- Do not bring magnetic objects close to the magnet. They should normally remain outside the 5 gauss limit. Never attempt to check for the presence of a magnetic field with ferromagnetic objects such as a standard tool. You are risking serious injury or damage to equipment or personnel, See figure ??.
- Only use non-magnetic storage/transport dewars and non-magnetic trolleys for liquid helium and liquid nitrogen.
- Use non-magnetic tools to work on a system if the magnet is energized.
- Remember that even non-magnetic electrically conductive materials may experience a force or resistance to motion due to field induced eddy currents.
- Give a verbal warning to people entering the room, remember that keys and coins are often magnetic.
- Ensure that there is sufficient ventilation.

10.3 EFFECTS ON PERSONNEL AND THE INSTRUMENTATION

Other equipment may be directly affected by the presence of large magnetic fields. The field may cause permanent damage or it may only have a temporary effect until the field is removed. Use a stray field map of your system and Table below to prove guidance. Table 9

Safe working field	Equipment or restriction
1 gauss	Image intensifiers Electron microscopes Accurate measuring scales Graphic terminals
5 gauss	Pacemakers Public access without warnings signs Cathode ray tubes
10 gauss	Computers

	Watches and clocks Credit cards
20 gauss	Magnetic storage media
50 gauss	Magnet power supply Shim coil power supply

Table 9 Guideline for safe location of some sensitive equipment

10.4 THRESHOLD LIMIT VALUES (TLV) FOR EXPOSURE TO MAGNETIC FIELDS

Guidelines on exposure to both static (DC) and time varying (AC) magnetic fields are constantly evolving as new scientific and medical evidence is presented. It is therefore wise to refer to official legislation standards for a list of relevant documentation.

Table below summarizes static field recommendation from 3 sources together with limits recently issued by the Council of European Union. These limits relate to occupational exposure by personnel who work with magnetic fields, they do not apply to the general public. Table 10]

Regulatory body	region	Time weighted average			Peak value		
		Whole Body	Limbs	Medical electronic device wearers	Whole Body	Limbs	Medical electronic device wearers
International Commission on Non-Ionizing Radiation Protection (ICNIRP) ⁷	Europe	200 milliTesla (over 8 hours)	200 milliTesla (over 8 hours)	No value available	2 Tesla	5 Tesla	0.5 milliTesla
National Radiological Protection Board (NRPB) ⁸	U.K.	200 milliTesla (over 24 hours)	200 milliTesla (over 24 hours)	No value available	2 Tesla	5 Tesla	0.5 milliTesla
American Conference of Governmental Industrial Hygienists (ACGIH) ⁹	U.S.A.	60 milliTesla (over 8 hours)	600 milliTesla (over 8 hours)	No value available	2 Tesla	5 Tesla	0.5 milliTesla
Council of the European Union ¹⁰ – active since April 2004	Europe	200 milliTesla (over 8 hours)	No value available	No value available	No value available	No value available	No value available

Table 10 TLVs for DC magnetic fields (1-10Hz)

In the context of magnetic supplied by oxford Instruments Nanoscience, AC magnetic fields of low frequency will be experienced if

- An operator is located within the stray field region when the magnet is being ramped up or down
- The operator moves into or out of the magnetic field.

TLV information for these cases is summarized in Table 11. The ICNIRP limits are closer to those being considered by the Council of European Union. As before these limits release to occupational exposure by personnel who work with magnetic fields, they do not apply to the general public.

Activity in static field region	Frequency (Hz)	ICNIRP (Europe) ¹¹ B (milliTesla)	NRPB (UK) ⁸ B (milliTesla)	ACGIH (USA) ⁹ B (milliTesla)
Slow head turning	1	200	80	60
Rapid head turning	2	50	40	30
	3	22	27	20
	4	13	20	15
	5	8	16	12
	6	6	13	10
Brisk walk in or out	7	4	11	9
Running in or out	8	3	10	8

Table 11 TLV for AC magnetic fields (1-8 Hz)

10.5 MEDICAL IMPLANTS

The operation of medical electronic implants, such as cardiac pacemakers, may be affected by static or changing magnetic fields.

Pacemakers do not all respond in the same way or at the same field level. You may not know that one of your visitors has a pacemaker so it is important to erect suitable signs to warn them of the danger. The stray fields caused by the magnet in other surrounding rooms may be enough to affect them.

Other medical implants, such as aneurysm clips, surgical clips or prostheses, may contain ferromagnetic materials. Therefore they may experience strong forces near the magnet which could result in injury or DEATH. Rapidly changing fields (for example pulsed gradient field) may induce eddy currents in any metallic implant, even if it is not magnetic, and generate heat.

10.6 SUPERCONDUCTING MAGNET QUENCHES

There is always the risk of a quench, even in a very reliable and stable magnet. External factors can affect the stability of the magnet so you should always be prepared. There are 3 effects that must be

considered; the collapse of the field, the possible generation of high voltages and the sudden release of cryogen as gas.



In the event of a magnet quench (either spontaneous or induced) the magnetic field will rapidly fall to zero. This may affect objects present in the room.

If you are using an Oxford Instrument Nanoscience power supply for the magnet the output current will automatically be switched off safely. Some large magnet systems are fitted with an Emergency Run Down Unit (ERDU).



Pressing the emergency run down button will make the magnet quench. There is always the risk that the quench will damage the magnet. Only use it if the magnetic field poses a serious threat to personnel, for example if someone has been trapped by a magnetic object.

In the event of a magnet quench all the cryogen may be released. The volumes of gases at room temperature will be approximately 70m³ for every 100 liters of cryogen (helium and nitrogen). Take precautions against asphyxiation.

If a superconducting magnet quenches releasing helium gas to the atmosphere you should evacuate the laboratory immediately and allow good ventilation until the helium gas has been dispersed if you do not do this you may be asphyxiated.

There is always a risk of magnet quenching. The stored energy in the magnet then evaporated most of the liquid helium very quickly. The helium recovery system is unlikely to be able to handle such a large amount of gas and the relief valve will release the excess gas into the laboratory displacing the air. If reasonably practicable, the cold gas should be vented in a safe area where nobody could be injured.

Actions following a magnet quench:

- In poorly ventilated areas, evacuate the room immediately and do not enter the room again until you know that there is sufficient oxygen in the air.
- Check that pressure relief valves have re-sealed properly so that they do not let air back into the system.
- Replace any broken bursting disks.
- Check that nitrogen vent ports are still clear.
- Refill the helium vessel.

- Carry out a standard 4.2 K electrical and continuity breakdown check
- Re-energize the magnet according to instructions given.

11 NANO TECHNOLOGY SAFETY

11.1 DEFINITION AND EXAMPLES

Nanotechnology is the field of science dealing with material specifically engineered to sizes of 100 nanometers ($1\text{ nm} = 10^{-9}\text{ m}$) or less. Nanoparticles are produced for their unique characteristics not attributed to common material dimensions. The different types of materials that are used in nanotechnology research and application vary widely; however, here are a few of the more common ones:

Carbon

Silver

Gold

Silica

Titanium

Polymers

Although many of these new hazards are still being investigated and toxicology research is in progress, few solid conclusions have been made about many nanomaterials. There are many things that we still do not know about this new technology. To properly protect against the unknown hazards that are involved while working with nanoparticles, conservative measures and best management practices must be exercised.

11.2 POTENTIAL HAZARDS

NIOSH (National Institute for Occupational Safety and Health) has determined the following potential exposure and health concerns:

The potential for nanomaterials to enter the body is among several factors that scientists examine in determining whether such materials may pose an occupational health hazard. Nanomaterials have the greatest potential to enter the body through the respiratory system if they are airborne and in the form of respirable-sized particles (nanoparticles). They may also come into contact with the skin or be ingested.

Based on results from human and animal studies, airborne nanoparticles can be inhaled and deposit in the respiratory tract; and based on animal studies, nanoparticles can enter the blood stream, and translocate to other organs.

Experimental studies in rats have shown that equivalent mass doses of insoluble incidental nanoparticles are more potent than large particles of similar composition in causing pulmonary

inflammation and lung tumors. Results from in vitro cell culture studies with similar materials are generally supportive of the biological responses observed in animals.

Studies in workers exposed to aerosols of some manufactured or incidental microscopic (fine) and nanoscale (ultrafine) particles have reported adverse lung effects including lung function decrements and obstructive and fibrotic lung diseases. Special requirements exist for the handling of free Carbon Nano-Tubes (and the other synthetic insoluble fibrous nanoparticles) since these are now suspected to act like asbestos fibres in the body. It is necessary to use a ducted and HEPA filtered cabinet and to follow very stringent handling procedures. The implications of these studies to engineered nanoparticles, which may have different particle properties, are uncertain.

11.3 RECOMMENDED WORK PRACTICES

- Always refer to the MSDS of the specific nanomaterial before using it in order to conduct a thorough risk assessment and take conservative measures to prevent exposure
- Work with nanomaterials in liquid media whenever possible
- Always wear proper personal protective equipment including gloves, lab coats or cleanroom suits, chemical splash goggles
- Use enclosed control systems, such as a glove box, or a fume hood when working with dry nanoparticles or when potential aerosol generation exists
- Immediately clean the work area by wet wiping method after each use and properly dispose of all contaminated materials (weighing dishes, paper towels etc.) into the designated laboratory waste container
- Using a vacuum cleaner equipped with a HEPA filter is an effective mean of removing nanoparticle contamination in case of spills

12 WASTE DISPOSAL PROCEDURES

12.1 CHEMICAL WASTE DISPOSAL

12.1.1 Waste Management Program

Sabancı University Services Department has a Chemical Waste Management Program. They collect chemical waste and arrange for proper disposal of the waste. In addition they manage the Hazardous Waste Minimization Program. Some general guidelines for chemical waste disposal are:

- a) Eliminate the need for disposal of unused chemicals by not purchasing more than the quantity of chemicals needed for your experiments.
- b) Try to use non-hazardous chemicals in place of hazardous chemicals whenever possible.
- c) Do not dispose of flammables, organic solvents, toxic materials, corrosive materials, reactive materials, odorous chemicals, or water insoluble materials down the drains.
- d) Dispose of Ethidium Bromide as a chemical hazardous waste. Refer to Section 12.2.6 for guidelines.

12.1.2 Waste Containers in the Laboratory

- a) Labeling:

- All waste containers must be labeled with the words “hazardous waste” or “laboratory waste,” the chemical composition of the waste, its hazards, and the accumulation start date (the date the waste is first produced). University Services requires a SUNUM “Hazardous Waste ID Tag” be completed and placed on the container when it is first designated as a waste. See APPENDIX A for an example tag.

- b) Accumulation time limits:

- S.U policy states that waste can only be stored in a lab for **90 days**. Full containers are required to be removed from labs within 2 weeks.

- c) Container and packaging requirements:

- The waste must be accumulated in containers that are in good condition.
- The waste must be compatible with the container it is stored in.
- The container must be kept closed except when the waste is being added to or removed from the container.

- Liquids must be collected in containers with screw tops or sealed lids. Do not completely fill the container. Leave the container less than 90% full.
- Dry waste must be double bagged in clear plastic bags. Bench diapers are not hazardous waste unless hazardous chemicals were spilled on the diaper.
- Liquids are required to be separated from solids (e.g., empty liquids from microfuge tubes).
- Mercury must be collected in a screw cap bottle. Double bag mercury contaminated items and broken thermometers in clear plastic bags.

d) Waste storage amount limits:

- The maximum amount of waste allowed to be stored in a laboratory is:
 - i. 10 LITERS
 - ii. **1 LITER** acute / extremely hazardous waste
 - iii. The maximum amount of **solvent** allowed to be stored in a lab is **50 LITERS** including waste solvents.

12.1.3 Chemical Waste Pick-Up Procedure

- a) Chemical waste is picked up on a regular schedule by University Services staff upon an 'INQUIRY from CALL CENTER'. Each laboratory must package, tag, and hand (See Section 4.6.6 for information on how to transport chemicals.) their waste to the pick-up site for their building at the scheduled time.
- b) Separate incompatible chemicals during transport and storage. Store and transport chemicals by hazard classes:
 - Flammable Solid
 - Flammable or Combustible Liquid/Solvent
 - nonhalogenated, halogenated
 - Corrosives
 - Acids – also separate organic, inorganic, nitric
 - Bases
 - Oxidizers
 - Poisons or Toxics
 - carcinogens, mutagens, irritants, formaldehyde
 - Explosives/Shock Sensitive

- Water reactives
- organic peroxides
- Heavy Metals

References to use to determine hazard classification and compatibility.

- the Aldrich chemical catalog
 - the label from the original chemical container
 - Sax N.I. and R.J. Lewis. 1989. Dangerous Properties of Industrial Materials. 7th Ed.
 - the MSDS
- c) These items will not be accepted at chemical waste pick-ups:
- Leaky containers.
 - Containers with exterior chemical contamination.
 - Containers which are too full. Do not fill containers over 90%.
 - Radioactive waste.
 - Bags containing protruding glass and other sharps such as needles, blades or glass pipettes.
 - Bench diapers unless hazardous chemicals were spilled on the diaper.

12.1.4 Dangerous Chemical waste, Unknowns, and Lab Clean-out Procedures

- a) Acutely dangerous waste
- Do not move acutely dangerous or unknown wastes which are shock sensitive or whose containers are leaking due to corrosion or which have no labels.
- b) Peroxide forming chemicals (PFCs)
- Once a peroxide forming chemical has been opened, the lab has one year to use it. After one year, it has to be disposed of as hazardous waste.
 - PFCs normally will not start forming explosive peroxides if they are not expired.
 - Refer to APPENDIX B for a list of peroxide forming chemicals and the disposal policy for PFCs.

12.2 BIOHAZARDOUS WASTE DISPOSAL

12.2.1 CONTAINMENT

- a) Use **RED** biohazard bags to contain biohazardous or medical waste. **Do not** use orange or clear bags.
- b) **RED** biohazard bags must be labeled with the words “**Biohazardous Waste**” or the word “**BIOHAZARD**” and the international biohazard symbol.

12.2.2 BIOHAZARD BAG CONTAINERS

- a) **RED** biohazard bags in use must be kept inside rigid, leak-resistant containers. The container must have a lid that fits. **Do not** use hampers or wire baskets to hold biohazard bags. **Do not** tape bags to the wall or equipment.
- b) The container can be any color.
- c) The container must be labeled “**Biohazardous Waste**” or with the word “**BIOHAZARD**” and the international biohazard symbol on the lids and sides so that the label is visible from any lateral direction.
- d) Biohazard waste containers must be sanitized when soiled with waste. They must be sanitized by exposure to hot water at 180°C for 15 seconds or exposure for 3 minutes to any one of the following disinfectants: hypochlorite (i.e., bleach) solution (500 ppm available chlorine), phenolic solution (100 ppm active agent), Iodoform solution (100 ppm iodine) or quaternary ammonium solution (400 ppm active agent).

12.2.3 SHARPS CONTAINERS

- a) All sharps containers must be rigid, puncture resistant and leak resistant. Cardboard does not meet these requirements.
- b) Sharps containers may be any color.
- c) Sharps containers must be labeled with the words, “**Sharps Waste**” or the international biohazard symbol and the word, “**BIOHAZARD.**”

12.2.4 BAG AND CONTAINER USE

- a) **Do not** overfill **RED** biohazard bags or the biohazard bag container. The lid must be able to fit tightly on the container and the bags must be able to be tied closed easily.
- b) Lids must be kept on containers unless the container is in use or the container is empty.
- c) **Never** allow sharps to stick out of the opening of the sharps container. Place them entirely inside the container.
- d) **Do not** use **RED** biohazard bags for regular trash, transporting non-biohazardous items, or covering equipment such as microscopes.
- e) **Do not** remove any biohazardous waste from the **RED** bag once it has been placed in the bag.
- f) **Do not** place items in the **RED** biohazard bag that can pierce the bag.

12.2.5 HUMAN TISSUES AND BIOHAZARDOUS ANIMALS

- a) Human tissues and biohazardous animals are required to be placed in **RED** biohazard bags. The bags are required to be placed inside a leak resistant container labeled with the words “Pathology Waste” or “PATH”.
- b) When storing human tissues or biohazardous animals that are waste in a freezer, the bags must be tagged with the date and a description of the contents. This is not required until the human or animal tissue becomes a waste.

12.2.6 GUIDELINES FOR THE DISPOSAL OF ETHIDIUM BROMIDE WASTE

Ethidium bromide (EtBr) is both an irritant and a mutagen. It may be harmful by inhalation, ingestion, or skin absorption. The material is irritating to the eyes, skin, mucous membranes, and upper respiratory tract. Chronic effects include the possible alteration of the genetic material. Ethidium bromide is a frameshift mutagen, which intercalates double-stranded DNA and RNA resulting in the inhibition of DNA synthesis. When possible, substitute with a less hazardous material in your procedures or use micro or semi-micro techniques to minimize the generation of hazardous waste.

Materials resulting from the use of ethidium bromide which need to be handled as hazardous waste include the following: ethidium bromide crystals or powder, stock solutions, gels, running buffers

and contaminated labware. Contaminated labware includes materials such as microfuge tubes, pipet tips, lab bench diapers, gloves, etc. that have come in contact with ethidium bromide. Dilute solutions of ethidium bromide (less than .01mg/l) may be deactivated in the lab by pouring the dilute solution through a commercially available filter cartridge designed to sequester EtBr and disposing the filtered liquid down the drain. Spent cartridges must be handled as hazardous waste.

The following procedures apply only for chemical waste, and not medical or radioactive waste. For medical or radioactive waste, follow the specific SUNM guidelines for disposal of medical or radioactive waste.

Preparation for Waste Collection and Storage

Gels:

Collect gels in clear containers that can be closed or sturdy (>4mm thick) clear bags. Double bag the gels. Seal the bags or close containers with tight sealing lids. Label the container or outer bag with a SUNUM Hazardous Waste Tag and store in a secondary container.

Crystals, powders, and stock solutions:

Label the original container or stock solution container with a SUNUM Hazardous Waste tag and store in a secondary container.

Contaminated labware (Dry waste):

Place contaminated labware in a sturdy (>4mm thick) clear bag. Double bag dry waste. Red biohazard bags containing EtBr dry waste will not be accepted. Sharps must be placed in an approved sharps container before being placed in a clear bag. Bags will not be accepted at the chemical waste pick-up with any protruding objects, such as pipets. Seal the bags and label the outer bag with a completed SUNUM Hazardous Waste Tag. The description should state "Ethidium Bromide Dry Waste."

12.2.7 TRANSPORT AND STORAGE

- a) Tie-close filled **RED** biohazard waste bags before transporting them.
- b) All closed and filled biohazard bags must be transported inside a rigid biohazard bag container and may be placed on a cart. The bag itself may not be transported in an autoclave pan, cardboard box, or on a cart. They may not be carried by hand.

- c) **Do not** set or store full, **RED** biohazard bags on the floor, in an autoclave pan or cardboard box. They must be inside a biohazard bag container at all times except when inside the autoclave.
- d) Store containers of biohazardous waste in a secure area such as a laboratory or autoclave room. **Do not** set or store them in the hallway.
- e) **Do not** store **RED** bags of biohazardous waste for more than 7 days at a temperature above freezing. Dispose of the bags as soon as possible.
- f) **Do not** store full sharps containers for more than 7 days at a temperature above freezing. Dispose of the full sharps containers as soon as possible.
- g) **Do not** store biohazardous waste, full sharps containers or human tissues and animals that are waste for more than 90 days in a freezer.
- h) **Do not** compact bags of biohazardous waste when placing them in a storage container.

12.2.8 TREATMENT /DECONTAMINATION

- Follow written procedures for treatment or decontamination of biohazardous waste and sharps waste.

12.2.9 DISPOSAL

- a) Dispose of all full, **RED** biohazard bags and sharps containers inside the biohazard containers provided by the treatment company. Keep the lid on the container except when placing bags or sharps containers inside. **Do not over fill the container.** The lid must fit on tightly on the container.
- b) Biohazardous waste or sharps waste combined with hazardous chemical waste must be disposed of as hazardous chemical waste.
- c) Biohazardous waste or sharps waste combined with radioactive waste must be disposed of as radioactive waste.
- d) Biohazardous waste or sharps waste combined with hazardous chemical waste and radioactive waste must be disposed of as radioactive waste.

12.3 NON-BIOHAZARDOUS SHARPS WASTE DISPOSAL

12.3.1 What Are Sharps?

- Needles with or without attached syringe or tubing,
- Blades, scalpels, razors,
- Glass: broken pipets, whole or broken Pasteur pipets, broken vials.

12.3.2 Disposal Procedures

- a) Do not discard sharps into the regular trash can. They can cause injury to the custodians.
- b) Do not recap or clip needles.
- c) As sharps are used or generated, place them into a sharps container. A **sharps container** is "a rigid puncture-resistant container which, when sealed, is leak-resistant and cannot be reopened without great difficulty". Do not use cardboard sharps containers because they leak. Use plastic or other kinds of leak-proof containers.
- d) Place sharps into a sharps container which is **not labeled with biohazardous stickers**. These containers do not have to be labeled in a specific way. When the container is nearly full, seal it and dispose of the sealed container with broken glass.

12.4 GLASS DISPOSAL

- 1) Do not mix broken or unbroken glass with regular trash. Glass mixed with regular trash could cause an injury to your custodian.
- 2) Dispose of large glass containers such as solvent bottles in the dumpsters located in the loading dock area. Rinse and dry the glass containers before disposal.
- 3) Dispose of broken glass in a separate trash container designated for and labeled "Broken Glass".

13 REFERENCES

[1] <http://adminservices.clayton.edu/ehs/labsafety.htm>, Clayton State University Environmental Health and Safety Home Page.

[2] <http://prtl.uhcl.edu/portal/page/portal/RSK/Safet>, University of Houston Clear Lake, Safety Home Page.

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<http://www.bc.edu/schools/cas/chemistry/facilities/nmrdocs/NMR%20Safety%20Plan.pdf>

<http://www.chem.usu.edu/facilities/nmr/saftyinformation.php>

http://www.ncsu.edu/ehs/www99/right/handsMan/worker/Cryogenic_Safety.htm

Cryogenic safety reference :

http://www.ncsu.edu/ehs/www99/right/handsMan/worker/Cryogenic_Safety.htm

APPENDIX A Waste Label

WASTE CHEMICAL LABEL

Lab: _____ Contact Person: _____

Room #: _____ Phone #: _____

COMPOSITION OF WASTE: (Please list ALL chemicals and % composition)

DO NOT USE ACRONYMS OR ABBREVIATIONS!

Waste Name:

Chemical Name:	% Composition:
----------------	----------------

_____	_____ %
_____	_____ %
_____	_____ %
_____	_____ %
_____	_____ %
_____	_____ %

TOTAL: 100%

CHECK ALL THAT APPLY

FLAMMABLE

CORROSIVE

POISON

OXIDIZER

REACTIVE

CARCINOGEN

LIQUID

SOLID

LIQUID/SOLID MIX

SUNUM LAB MANAGEMENT: 2444

APPENDIX B PEROXIDE FORMING CHEMICALS

PFCs normally will not start forming these explosive peroxides if they are not expired. It is important for the user to keep a record of when these PFCs will expire so you will not have to pay any additional disposal costs.

Materials that are susceptible to peroxide formation (i.e., autooxidation) are ones that typically react with air, moisture, or impurities and produce a change in their chemical composition in normal storage. Peroxides are highly reactive and can explode upon shock or spark. The peroxides that form are less volatile than the solvent itself and thus tend to concentrate. This is particularly dangerous if peroxides are present during a distillation, where the applied heat to the concentrated solution may trigger a violent explosion. Equally dangerous is to allow a container of this material to evaporate to dryness, leaving the crystals of peroxide at the bottom of the container. Each container of peroxide forming chemicals should be dated with the date received and the date first opened. There are three classes of peroxide forming chemicals. The examples listed below each class do not compose a complete list of peroxide forming chemicals.

Disposal Requirements

Class 1

These chemicals form peroxides after prolonged storage. These chemicals should be tested for the formation of peroxides on a periodic basis. Several methods are available to check for peroxides. The two most common are the use of peroxide test strips or the potassium iodide test.

Isopropyl ether	Potassium amide	Divinyl ether
Divinyl acetylene	Vinylidene chloride	
Sodium amide	Potassium metal	

Class 2

This group of chemicals will readily form peroxides when they become concentrated (i.e. evaporation or distillation). The concentration process will defeat the action of most auto-oxidation inhibitors. These chemicals should be disposed of within 12 months of receiving.

Diethylether	Methyl isobutyl ketone	Furan
Tetrahydrofuran	Ethylene glycol dimethyl ether	Vinyl ethers
Dioxane	Dicyclopentadiene	Cyclohexene
Acetal	Diacetylene	Cumene
Methylacetylene	Tetrahydronaphthalene	
Cyclopentene	Methylcyclopentane	

Class 3

This group of chemicals form peroxides due to initiation of polymerization. When stored in a liquid state, the peroxide forming potential dramatically increases. These chemicals should be disposed of if they become degraded or are no longer needed.

Butadiene	Vinyl pyridine	Acrylic acid
Styrene	Vinyl chloride	Methyl methacrylate
Tetrafluoroethylene	Chlorobutadiene	Vinylidene chloride
Vinyl acetylene	Chlorotrifluoroethylene	
Vinyl acetate	Acrylonitrile	

Procedures for handling and storage of Peroxide Forming Materials

- 1) Minimize the quantity of peroxide forming chemicals stored in the lab.
- 2) Try to avoid over ordering (bulk purchases) of PFCs (peroxide forming chemicals) that will not be used within the allotted time.
- 3) Carefully review all cautionary material supplied by the manufacturer prior to use.
- 4) Segregate these compounds from other classes of chemicals that could create a serious hazard to life or property should an accident occur (i.e. acids, bases, oxidizers and etc.).
- 5) Date all containers of peroxide forming chemicals when they first arrive to the lab.
- 6) Never return unused quantities back to the container (contamination).
- 7) Clean up all spills immediately.
- 8) Avoid evaporation or distillation, since distillation defeats the stabilizer added to the solvents.
- 9) Ensure containers are tightly sealed to avoid evaporation.
- 10) Ensure containers are free of exterior contamination or crystallization.
- 11) Routinely test for the formation of peroxides using one of the approved methods.
- 12) Dispose of ethyl ether, and other volatile peroxide forming compounds, within 12 months.

- 13) If old containers of peroxide forming chemicals are discovered in the lab, (greater than two years past the expiration date or if the date of the container is unknown) **do not handle the container**. If crystallization is present in or on the exterior of a container, **do not handle the container**, secure it and contact Lab Supervisors.
- 14) Complete hazardous waste tags for expired, degraded, or unwanted peroxide forming chemicals and take them to the next designated hazardous waste pick-up.

APPENDIX C Gases used in SUNUM

The following gases present special hazards either due to their toxicity or physical properties.

Review this information before using these gases.

-
- Acetylene
- Ammonia (NH₃)
- Boron trichloride
- Chlorine
- Hydrogen
- Methane
- Nitrous Oxide (N₂O)
- Octafluorocyclobutane
- Oxygen
- Silane
- Sulfur Hexafluoride
- Trifluoromethane (CHF₃)
- Tetrafluoromethane (CF₄)

a. Acetylene

Overview

Acetylene is highly flammable under pressure and is spontaneously combustible in air at pressures above 15 psig. Acetylene cylinders do not contain oxygen and may cause asphyxiation if released in a confined area. Since acetylene is shock-sensitive and explodes above 30 psi, cylinders of acetylene contain acetylene dissolved in acetone. Acetylene cylinders must not be placed on their sides, since the acetone and binders will have dislodged. The result may be formation of acetylene "pocket" that is subject to polymerization and the possibility that liquid acetone will be released into the regulator.

Emergency Procedures

In case of skin contact: Skin effects are not likely. Contact with liquid acetylene may cause irritation upon repeated exposures. Wash affected area(s) with soap and warm water. If irritation develops, seek medical attention.

In case of eye contact: Not a likely route of exposure since acetylene is a gas at room temperature. Contact of liquid acetylene with the eyes may cause temporary irritation. Flush with water for at least 15 minutes. Seek medical attention as needed.

In case of inhalation: Acetylene is an asphyxiant and may cause anesthetic effects at high concentrations. Victims should be assisted to an uncontaminated area with fresh air.

In case of ingestion: Not a likely route of exposure since acetylene is a gas at room temperature.

Handling

Acetylene is shipped in a cylinder packed with a porous mass material and a liquid solvent, commonly acetone. When the valve of a charged acetylene cylinder is opened, the acetylene comes out of solution and passes out in the gaseous form. IT IS CRUCIAL THAT FUSE PLUGS IN THE TOPS AND BOTTOMS OF ALL ACETYLENE CYLINDERS BE THOROUGHLY INSPECTED WHENEVER HANDLED TO DETECT SOLVENT LOSS. There should be no sources of ignition in the storage or use area. If rough handling or other occurrences should cause any fusible plug to leak, move the cylinder to an open space well away from any possible source and place a sign on the cylinder warning of "Leaking Flammable Gas". Contact SUNUM Facility Management at **7474 (0-216-568-7474)**.

Storage

Do not store acetylene cylinders on their side. If an acetylene cylinder has tipped over or was stored on its side, carefully place the cylinder upright and do not use until the liquid has settled to the bottom. The rule of thumb is not to use the cylinder for as many minutes as the cylinder was on its side, up to 24 hours.

Disposal

Acetylene cylinders should be returned to the compressed gas distributor when emptied or no longer used.

For More Information

See the MSDS for acetylene from [Linde Gases](#).

b. Ammonia (NH₃)

Overview

Ammonia is an irritant and corrosive to the skin, eyes, respiratory tract and mucous membranes. May cause severe burns to the eyes, lungs and skin. Skin and respiratory related diseases could be aggravated by exposure.

Emergency Procedures

In case of skin contact: Immediate medical attention is required. Wash off immediately with soap and plenty of water for at least 15 minutes while removing all contaminated clothing and shoes.

In case of eye contact: Immediate medical attention is required. Immediately flush with plenty of water. After initial flushing, remove any contact lenses and continue flushing for at least 15 minutes. Keep eye wide open while rinsing. Do not rub affected area.

In case of inhalation: Corrosive to respiratory tract Irritating to respiratory system. Irritating to respiratory system. Can cause severe lung damage. May be fatal if inhaled. Delayed adverse effects possible. Prolonged exposure to small concentrations may result in pulmonary edema. Delayed fatal pulmonary edema possible.

In case of ingestion: Immediate medical attention is required. Do NOT induce vomiting. Drink plenty of water. Never give anything by mouth to an unconscious person. Call a physician or Poison Control Center immediately

Handling

Wear personal protective equipment. Avoid contact with skin, eyes and clothing.

Keep away from heat, sparks and open flame. No smoking. To avoid ignition of vapors by static electricity discharge, all metal parts of the equipment must be grounded. When moving cylinders, even for short distance, use a cart designed to transport cylinders.

Use only in ventilated areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur.

Use an adjustable strap wrench to remove over-tight or rusted caps. Close valve after each use and when empty. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

For additional recommendations consult Compressed Gas Association's (CGA) Safety Bulletin SB-2, Oxygen-Deficient Atmospheres. For additional handling recommendations, consult Compressed Gas Association Pamphlets P-1, G-2, G-2.1, G-2.2, and P-26. For additional recommendations

consult Compressed Gas Association's (CGA) Safety Bulletin SB-2, Oxygen-Deficient Atmospheres.

Storage

Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal.

For More Information See the MSDS for chlorine from [Linde Gases](#).

c. Boron trichloride (BCl₃)

Overview

May cause respiratory tract burns, skin burns, eye burns, mucous membrane burns. Containers may rupture or explode if exposed to heat. May react on contact with water. Releases toxic, corrosive, flammable or explosive gas

Emergency Procedures

In case of skin contact: Immediate medical attention is required. Wash off immediately with plenty of water removing all contaminated clothes and shoes

In case of eye contact: Immediate medical attention is required. In case of contact with substance, immediately flush eyes with running water for at least 30 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing.

In case of inhalation: PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF INHALATION OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Conscious inhalation victims should be assisted to an uncontaminated area and inhale fresh air. If breathing is difficult, administer oxygen. Unconscious persons should be moved to an uncontaminated area and, as necessary, given artificial resuscitation and supplemental oxygen. Treatment should be symptomatic and supportive.

In case of ingestion: None under normal use. Call a POISON CENTER or doctor/physician if exposed or you feel unwell.

Handling

Any materials suitable for use with anhydrous hydrogen chloride may be used with boron trichloride. Keep equipment scrupulously dry.

Do not breathe gas. Avoid contact with skin, eyes and clothing. Use only in ventilated areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur.

Use an adjustable strap wrench to remove over-tight or rusted caps. Close valve after each use and when empty. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit

Storage

Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below

52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal. For

More Information

See the MSDS for diborane from [Linde Gases](#).

d. Chlorine (Cl₂)

Overview

Highly toxic agent via inhalation and ingestion. Primarily an intense respiratory irritant and a major potential hazard upon contact to skin and eyes. Sufficient concentration of the gas irritates the mucous membranes. It can cause pulmonary edema. Liquid chlorine in contact with skin will cause frostbite, smarting of the skin and first-degree burns on short exposure; may cause secondary burns on long exposure. Vapors will cause severe irritation of eyes and throat and can cause eye and lung injury. Vapors cannot be tolerated even at low concentrations. In extreme cases, difficulty of breathing may increase to the point where death can occur from suffocation. The characteristic, penetrating odor of chlorine gas gives warning of its presence in the air.

Emergency Procedures

In case of skin contact: Gas can cause irritation. Contact with liquid causes severe corrosive action. Reacts with water very rapidly yielding hydrochloric acid. Hydrogen chloride burns exhibit severe pain, redness, possible swelling and early necrosis.

In case of eye contact: Gas can cause irritation. Contact with liquid causes severe corrosive action. Risk of serious damage to eyes.

In case of inhalation: Fatal if inhaled. Inhalation of corrosive fumes/gases may cause coughing, choking, headache, dizziness, and weakness for several hours. Pulmonary edema may occur with tightness in the chest, shortness of breath, bluish skin, decreased blood pressure, and increased heart rate. Chemical pneumonitis and pulmonary edema result from exposure to the lower respiratory tract and deep lung. Residual pulmonary malfunction might occur.

In case of ingestion: Not an expected route of exposure. Ingestion causes burns of the upper digestive and respiratory tract.

Handling

Most metals corrode rapidly with wet chlorine. Systems must be kept dry. Lead, gold, tantalum and Hastelloy are most resistant to wet chlorine.

Do not breathe gas. Avoid contact with skin, eyes and clothing. Use only in ventilated areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur. "NO SMOKING" signs should be posted in storage and use areas.

Use an adjustable strap wrench to remove over-tight or rusted caps. Close valve after each use and when empty. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit

Storage

Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

For additional storage recommendations, consult the CHLORINE INSTITUTE PAMPHLET 1.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal.

For More Information

See the MSDS for chlorine from [Linde Gases](#).

e. Hydrogen (H₂)

Overview

Hydrogen is a flammable, colorless, odorless, compressed gas packaged in cylinders at high pressure. It poses an immediate fire and explosive hazard when concentrations exceed 4%. It is much lighter than air and burns with an invisible flame. High concentrations that will cause suffocation are within the flammable range and must not be entered

Emergency Procedures

In case of skin contact: None known. Contact with rapidly expanding gas near the point of release may cause frostbite.

In case of eye contact: None known. Contact with rapidly expanding gas near the point of release may cause frostbite.

In case of inhalation: Simple asphyxiant. May cause suffocation by displacing the oxygen in the air. Exposure to oxygen deficient atmosphere (<19.5%) may cause dizziness, drowsiness, nausea, vomiting, excess salivation, diminished mental alertness, loss of consciousness and death. Exposure to atmospheres containing 8-10% or less oxygen will bring about unconsciousness without warning and so quickly that the individuals cannot help or protect themselves. Lack of sufficient oxygen may cause serious injury or death.

In case of ingestion: Not an expected route of exposure.

Handling

Ground and bond all lines and equipment associated with the hydrogen system. All equipment should be non-sparking and explosion proof. Separate hydrogen from oxygen and other oxidizers by a minimum distance of 20 ft. or by a 5 ft. high barrier with a minimum fire resistance rating of a half an hour. Post "NO SMOKING" signs in use and storage areas. Remove all sources of ignition. Use only in ventilated areas. Hydrogen is non-corrosive. However hydrogen can interact with metals (hardened steels) to cause embitterment.

Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur. "NO SMOKING" signs should be posted in storage and use areas.

Use an adjustable strap wrench to remove over-tight or rusted caps. Close valve after each use and when empty. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit

Storage

Outside or detached storage is preferred. Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal.

For More Information

See the MSDS for chlorine from [Linde Gases](#).

f. Methane (CH₄)

Overview

Methane is a colorless and odorless gas. It is not toxic; the immediate health hazard is that it may cause thermal burns. It is flammable and may form mixtures with air that are flammable or explosive. Methane is violently reactive with oxidizers, halogens, and some halogen compounds. Methane is an asphyxiant and may displace oxygen in a workplace atmosphere. The concentrations at which flammable or explosive mixtures form are much lower than the concentration at which asphyxiation risk is significant.

Emergency Procedures

In case of skin contact: No detrimental effect of skin contact has been reported. Treat thermal burns by assuring that affected area is cool by flushing with cool water, then apply dry sterile dressings. If the patient is burned on the face, neck, head, or chest, assume that the airway may also have been burned and obtain professional medical assistance immediately.

In case of eye contact: No detrimental effect of eye contact has been reported

In case of inhalation: PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF INHALATION OVEREXPOSURE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS. Conscious inhalation victims should be assisted to an uncontaminated area and inhale fresh air. If breathing is difficult, administer oxygen. Unconscious persons should be moved to an uncontaminated area and, as necessary, given artificial resuscitation and supplemental oxygen. Treatment should be symptomatic and supportive.

In case of ingestion: None under normal use. Get medical attention if symptoms occur.

Handling

Ground and bond all lines and equipment associated with product system. All equipment should be non-sparking and explosion proof. Remove all sources of ignition. Use only in ventilated areas. "NO SMOKING" signs should be posted in storage and use areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping.

Use an adjustable strap wrench to remove over-tight or rusted caps. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

Storage

Outside or detached storage is preferred. Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal.

For More Information

See the MSDS for fluorine from [Linde Gases](#).

g. Nitrous Oxide (N₂O)

Overview

Nitrous Oxide is a colorless, nonflammable gas or a colorless, refrigerated liquid. The gas and liquid have a sweet odor. The refrigerated liquid will rapidly boil to the gas at standard temperatures and pressures. At high concentrations, Nitrous Oxide is an anesthetic and overexposure will produce symptoms of drowsiness, weakness, and loss of coordination. At higher concentrations, the gas will act as an asphyxiant by displacing oxygen. The liquefied gas can cause frostbite to any contaminated tissue. Nitrous Oxide presents a reproductive hazard which can cause embryotoxic, fetotoxic and teratogenic effects, based on human information. Nitrous oxide is not flammable, but at elevated temperatures or if involved in a fire, the gas can act as an oxidizer to initiate and sustain the combustion of flammable materials. Adequate fire protection must be provided.

Emergency Procedures

In case of skin contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of eye contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of inhalation: Simple asphyxiant. May cause suffocation by displacing the oxygen in the air. Exposure to oxygen deficient atmosphere (<19.5%) may cause dizziness, drowsiness, nausea, vomiting, excess salivation, diminished mental alertness, loss of consciousness and death. Exposure to atmospheres containing 8-10% or less oxygen will bring about unconsciousness without warning and so quickly that the individuals cannot help or protect themselves. Lack of sufficient oxygen may cause serious injury or death. Anesthetic effects may occur when mixed with oxygen at a ratio of 80% nitrous oxide to 20% oxygen. Laughter effects seem to occur after incipient asphyxia accompanied by the sudden return of oxygen. Nitrous oxide is a slight narcotic. Intentional misuse by deliberately concentrating and inhaling contents may be harmful or fatal

In case of ingestion: None under normal use. Get medical attention if symptoms occur.

Handling

Some metals such as carbon steel will become brittle at low temperatures and easily fracture. Use only in ventilated areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur. "NO SMOKING" signs should be posted in storage and use areas.

Use a pressure reducing regulator when connecting cylinder to lower pressure piping or systems.

Liquid Density at Boiling Point; 76.34 lb/ft³ (1222.8 Kg/m³).

Use an adjustable strap wrench to remove over-tight or rusted caps. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Due to increased misuse and abuse of nitrous oxide, handling and storage precautions should be implemented to prevent theft and improper use. The following recommendations may not include all precautions which are necessary. Nitrous oxide systems should be installed in accordance with CGA G-8.1, "Standard for Nitrous Oxide Systems at Consumer Sites". Keep full and empty nitrous oxide containers and utilization equipment stored in a secured area. Allow only authorized personnel to remove containers, inventory and account for both full and empty containers and bulk product. Promptly report any theft of nitrous oxide to the police and the supplier. Establish other procedures as necessary to check for unusual use or loss of nitrous oxide.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

For additional recommendations, consult Compressed Gas Association's Pamphlet G-8.2 and SB-6

Storage

Outside or detached storage is preferred. Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be

segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal.

For More Information

See the MSDS for fluorine from [Linde Gases](#).

h. Octafluorocyclobutane (C₄F₈)

Overview

Octafluorocyclobutane is a colorless, odorless, nonflammable, liquefied gas. Octafluorocyclobutane is an asphyxiant and presents a significant health hazard by displacing the oxygen in the atmosphere. Frostbite can be caused by contact with rapidly expanding gases or the liquefied gas. This gas is not flammable. However, if involved in a fire, this product can decompose to produce toxic gases (i.e. hydrogen fluoride, carbonyl fluoride). This gas is not reactive. Release of this gas is not expected to cause environmental harm; however, all accidental or intentional release should be avoided. Provide adequate fire protection during emergency response.

Emergency Procedures

In case of skin contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of eye contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of inhalation: High concentrations may cause asphyxia from lack of oxygen or act as a narcotic causing central nervous system depression. Symptoms of overexposure are dizziness,

headache, tiredness, nausea, unconsciousness, cessation of breathing. Oxygen deficiency may occur in the presence of high concentrations resulting in asphyxiation. Maintain oxygen levels at or above 19.5%.

In case of ingestion: Not an expected route of exposure.

Handling

Use only in ventilated areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur.

Use an adjustable strap wrench to remove over-tight or rusted caps. Close valve after each use and when empty. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

Product is non-corrosive and may be used with any common structural material. Silver and carbon bearing alloys can act as catalysts for decomposing the product at high temperatures. Alloys containing more than 2% magnesium should not be used if water is present.

For additional recommendations consult Compressed Gas Association's (CGA) Safety Bulletin SB-2, Oxygen-Deficient Atmospheres.

Storage

Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal.

For More Information

See the MSDS for chlorine from [Linde Gases](#).

i. Oxygen (O₂)

Overview

Oxygen gas is a powerful oxidizer which will rapidly accelerate combustion of many materials. Oxygen cylinders should be handled with care because serious explosions have resulted from contact between oil and high pressure oxygen. Oil or grease should never be used on connections to oxygen cylinder or gas line carrying oxygen. Oxygen is incompatible with all flammable materials and should be stored separately.

Emergency Procedures

Oxygen is non-toxic under the conditions of usual laboratory use. Liquid oxygen is [cryogenic](#) and is capable of causing severe tissue damage upon exposure.

Handling

Never allow oil, greases and other readily combustible substances to come in contact with oxygen cylinders, valves, regulators, and fittings.

Follow all [compressed gas general handling precautions](#) when working with oxygen. Oxygen should not be used as a substitute for compressed air in pneumatic equipment since this type generally contains flammable lubricants. Contact of liquid oxygen with many organic substances can lead to an explosion.

Storage

Oxygen cylinders in storage must be separated from any flammable gas or combustible material by a distance of 20 feet or a non-combustible 5-foot wall with a fire rating of at least one half hour.

Disposal

Oxygen cylinders should be returned to the compressed gas distributor when emptied or no longer used.

For More Information

See the MSDS for oxygen from [BOC Gases](#).

j. Silane (SiH₄)

Overview

Silane is a colorless gas with a repulsive odor. The immediate health hazard is that it may cause thermal burns. It is flammable and pyrophoric (autoigniting in air), but may form mixtures with air that do not autoignite, but are flammable or explosive. Silane is violently reactive with oxidizers and halogens

Emergency Procedures

In case of skin contact: Flush with a copious stream of water while removing contaminated clothing. Continue flushing until the professional medical assistance arrives, but for no less than fifteen minutes. Treat thermal burns by assuring that affected area is cool by flushing with cool water, then apply dry sterile dressings. If the patient is burned on the face, neck, head, or chest, assume that the airway may also have been burned and obtain professional medical assistance immediately.

In case of eye contact: Flush continuously with clean water until the professional medical assistance arrives, but for no less than thirty minutes. Continuation of flushing until patient is transferred to an ophthalmologist or emergency physician is recommended.

In case of inhalation: This is the primary route of exposure.

- 1) Remove the affected person from the gas source or contaminated area. Note: Personal Protective Equipment (PPE), including positive pressure, self contained breathing apparatus, may be required to assure the safety of the rescuer.
- 2) If the affected person is not breathing spontaneously, administer rescue breathing.
- 3) If the affected person does not have a pulse, administer CPR.
- 4) If medical oxygen and appropriately trained personnel are available, administer 100% oxygen to the affected person.
- 5) Summon an emergency ambulance. If an ambulance is not available, contact a physician, hospital, or poison control center for instruction.
- 6) Keep the affected person warm, comfortable, and at rest while awaiting professional medical care. Monitor the breathing and pulse continuously. Administer rescue breathing or CPR if necessary.

In case of ingestion: Not a likely route of exposure since silane is a gas at room temperature. If swallowed, drink two glasses of water or milk. Do not induce vomiting.

Handling

Handle in sealed, purged system. Ground and bond all lines and equipment associated with product system. All equipment should be non-sparking and explosion proof. Remove all sources of ignition. Use only in ventilated areas. "NO SMOKING" signs should be posted in storage and use areas.

Pure silane is non-corrosive and may be handled in most common structural containers. Carbon steel, stainless steel, brass, Monel® & Hasteloy C are most commonly used materials. It also compatible with ordinary glass, Pyrex®, and quartz. For gasket materials, Viton®, Nylon, Teflon®, and Kel-F® are all satisfactory. Most all silane leaks will ignite in air producing silicon dioxide. Occasionally the silicon dioxide will slow or stop the leak. Materials may accumulated behind outlet plug. Wear appropriate protective equipmet and face outlet away when removing plug and connecting cylinder.

Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping.

Use an adjustable strap wrench to remove over-tight or rusted caps. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

Storage

Outside or detached storage is preferred. Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal

For More Information

See the MSDS for silane from [Linde Gases](#).

(<http://web.princeton.edu/sites/ehs/labsafetymanual/sec7e.htm>)

k. Sulfur Hexafluoride (SF₆)

Overview

Can cause rapid suffocation. Compressed liquefied gas. Avoid breathing gas. Direct contact with liquid can cause frostbite. Self contained breathing apparatus (SCBA) may be required.

Emergency Procedures

In case of skin contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of eye contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of inhalation: Simple asphyxiant. May cause suffocation by displacing the oxygen in the air. Exposure to oxygen deficient atmosphere (<19.5%) may cause dizziness, drowsiness, nausea, vomiting, excess salivation, diminished mental alertness, loss of consciousness and death. Exposure to atmospheres containing 8-10% or less oxygen will bring about unconsciousness without warning and so quickly that the individuals cannot help or protect themselves. Lack of sufficient oxygen may cause serious injury or death

In case of ingestion: Not an expected route of exposure.

Handling

Aluminum, stainless steel, copper, brasses and silver recommended for temperatures above 400°F (204°C) to prevent decomposition to toxic fluoride compounds.

Use only in ventilated areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur.

Use an adjustable strap wrench to remove over-tight or rusted caps. Close valve after each use and when empty. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

For additional recommendations consult Compressed Gas Association's Pamphlets P-1 and Safety Bulletin SB-2.

Storage

Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal.

For More Information

See the MSDS for chlorine from [Linde Gases](#).

1. Trifluoromethane (CHF₃)

Overview

This product does not contain oxygen and may cause asphyxia if released in a confined area. Fluorocarbons can cause irritation, central nervous system depression and irregular heart beat at high concentrations. Nonflammable but decomposes to toxic gases, including hydrofluoric, under fire conditions.

Emergency Procedures

In case of skin contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of eye contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of inhalation: High concentrations may cause asphyxia from lack of oxygen or act as a narcotic causing central nervous system depression. Symptoms of overexposure are dizziness, headache, tiredness, nausea, unconsciousness, cessation of breathing. Oxygen deficiency may occur in the presence of high concentrations resulting in asphyxiation. Maintain oxygen levels at or above 19.5%.

In case of ingestion: Not an expected route of exposure.

Handling

Use only in ventilated areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur.

Use an adjustable strap wrench to remove over-tight or rusted caps. Close valve after each use and when empty. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

Product is non-corrosive and may be used with any common structural material. Silver and carbon bearing alloys can act as catalysts for decomposing the product at high temperatures. Alloys containing more than 2% magnesium should not be used if water is present.

For additional recommendations consult Compressed Gas Association's (CGA) Safety Bulletin SB-2, Oxygen-Deficient Atmospheres.

Storage

Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE to Linde for proper disposal.

For More Information

See the MSDS for chlorine from [Linde Gases](#).

m. Tetrafluoromethane (CF₄)

Overview

This product does not contain oxygen and may cause asphyxia if released in a confined area. Fluorocarbons can cause irritation, central nervous system depression and irregular heart beat at high concentrations. Nonflammable but decomposes to toxic gases, including hydrofluoric, under fire conditions.

Emergency Procedures

In case of skin contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of eye contact: This product is a gas at room temperature. Contact with liquid may cause frostbite.

In case of inhalation: High concentrations may cause asphyxia from lack of oxygen or act as a narcotic causing central nervous system depression. Symptoms of overexposure are dizziness, headache, tiredness, nausea, unconsciousness, cessation of breathing. Oxygen deficiency may occur in the presence of high concentrations resulting in asphyxiation. Maintain oxygen levels at or above 19.5%.

In case of ingestion: Not an expected route of exposure.

Handling

Use only in ventilated areas. Never attempt to lift a cylinder by its valve protection cap. Protect cylinders from physical damage; do not drag, roll, slide or drop. When moving cylinders, even for short distance, use a cart designed to transport cylinders. Use equipment rated for cylinder pressure. Use backflow preventive device in piping. Never insert an object (e.g. wrench, screwdriver, pry bar, etc.) into valve cap openings. Doing so may damage valve, causing leak to occur.

Use an adjustable strap wrench to remove over-tight or rusted caps. Close valve after each use and when empty. If user experiences any difficulty operating cylinder valve discontinue use and contact supplier.

Never put cylinders into trunks of cars or unventilated areas of passenger vehicles. Never attempt to refill a compressed gas cylinder without the owner's written consent. Never strike an arc on a compressed gas cylinder or make a cylinder a part of an electrical circuit.

Product is non-corrosive and may be used with any common structural material. Silver and carbon bearing alloys can act as catalysts for decomposing the product at high temperatures. Alloys containing more than 2% magnesium should not be used if water is present.

For additional recommendations consult Compressed Gas Association's (CGA) Safety Bulletin SB-2, Oxygen-Deficient Atmospheres.

Storage

Protect from physical damage. Cylinders should be stored upright with valve protection cap in place and firmly secured to prevent falling. Store in cool, dry, well-ventilated area of non-combustible construction away from heavily trafficked areas and emergency exits. Keep at temperatures below 52°C / 125°F. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full cylinders from being stored for excessive periods of time. Always store and handle compressed gas cylinders in accordance with Compressed Gas Association, pamphlet CGA-P1, Safe Handling of Compressed Gases in Containers.

Disposal

Do not attempt to dispose of residual waste or unused quantities. Return in the shipping container **PROPERLY LABELED WITH ANY VALVE OUTLET PLUGS OR CAPS SECURED AND VALVE PROTECTION CAP IN PLACE** to Linde for proper disposal.

For More Information

See the MSDS for chlorine from [Linde Gases](#).

APPENDIX D *MSDS GLOSSARY*

ACGIH	American Conference of Governmental Industrial Hygienists . A professional organization of government and university industrial hygienists.
Acute Health Effect	An adverse effect arising from a short (minutes to hours) period of exposure.
AIHA	American Industrial Hygiene Association . A professional organization of industrial hygienists.
Article	Defined by OSHA as "any manufactured item other than a fluid or particle which is formed to a specific shape or design during manufacture, has end use function(s) dependent in whole or in part upon its shape or design during end use, and which under normal conditions of use does not release more than... minute or trace amounts of a hazardous chemical and does not pose a physical hazard or health risk to Students, faculty and lab associatess".
CAS Number	Chemical Abstracts Service number - a way in which chemicals are uniquely identified by a numbering system.
Ceiling Limit	A designated maximum airborne level to which people can be exposed.
Chronic Health Effect	An adverse effect arising after long periods (months to years) of exposure.
Hazardous chemical	Any chemical that is a physical hazard or a health hazard .
Health Hazard	Includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes.

Lethal Dose (LD50)	The dose producing death in 50% of a test animal population
Lower Explosive Limit (LEL)	The minimum concentration as a percentage, of flammable gas that can be ignited. Also referred to as the Lower Flammable Limit (LFL)
Lowest Lethal Concentration (LCLo)	The lowest concentration of a substance in air that has been known to kill animals
Lowest Toxic Dose (TDLo)	<p>The lowest dose reported to cause toxic effects in humans or test animals.</p> <p>Permissible Exposure Limit - Permissible concentration in air of a substance to which nearly all workers may be repeatedly exposed 8 hours a day, 40 hours a week, for 30 years without adverse side effects. This value is legally enforceable by OSHA.</p>
mg/m³	Concentration measurement in milligrams per cubic meter.
MSDS	Material Safety Data Sheet
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational Exposure Limit - A health based workplace standard to protect workers from adverse exposure. For example, TLV or PEL.
OSHA	<p>Occupational Safety and Health Administration. Located within the US Department of Labor. The agency responsibilities include formulating occupational safety and health standards and inspecting workplaces to ensure compliance with these standards.</p>

PEL	Permissible Exposure Limit - the maximum eight-hour time-weighted-average air concentration to which Students, faculty and lab associates can be exposed. This level is enforced by OSHA.
PEL-STEL	Permissible Exposure Limit-Short Term Exposure Limit - 15 min Time Weighted Average exposure that shall not be exceeded at any time during a workday.
Physical Hazard	A chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water - reactive.
PPE	Personal Protective Equipment - Includes items such as gloves, safety goggles and respirator masks that are worn to reduce the potential for exposure to chemicals.
PPM	Concentration in parts per million (by volume). Label Any written, printed, or graphic material displayed on or affixed to containers of hazardous chemicals.
STEL	Short Term Exposure Limit - Maximum concentration for continuous 15 minute period, allowed four times a day with at least 60 minutes between exposures
TWA	Time Weighted Average - The average exposure for an individual over a given working period (normally 8 hours).
TLV	Threshold Limit Value - An exposure level under which most people can work consistently for 8 hours a day, without adverse effects. Can also be used with 15-minute Short Term Exposure Limits. This exposure level was developed by the ACGIH and is not a legally enforceable value.
(UEL) Upper Explosive Limit	Percentage by volume of a flammable gas or vapor that is the maximum level ignitable. Also referred to the Upper Flammable Limit (UFL).

WEEL Workplace Environmental Exposure Level - exposure guidelines developed by [AIHA](#).

MSDS Laboratory Links

<http://www.airgas.com/home.aspx>

<http://ccinfoweb.ccohs.ca/msds/search.html>

<http://www.phac-aspc.gc.ca/msds-ftss/>

<http://www.sigmaaldrich.com/united-states.html>

<http://hazard.com/msds/>

<http://www.cdms.net/>

<http://www.msdssearch.com/>

Material Safety Data Sheet (MSDS) Resources

- [CCOHS MSDS database](#)
- [Additional Chemical Safety Resources](#)

Hazardous Substances Data Bank (HSDB)

Comprehensive, peer-reviewed toxicology data for about 5,000 chemicals.

<http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>

HSDB is a toxicology data file on the National Library of Medicine's (NLM) Toxicology Data Network (TOXNET®). It contains information on human exposure, industrial hygiene, emergency handling procedures, environmental fate, regulatory requirements, and related areas. All data are referenced and derived from a core set of books, government documents, technical reports and selected primary journal literature.