Harvard University
Center for Nanoscale Systems
Safety Manual

EMERGENCY CONTACTS

FIRE OR MEDICAL **911**

PUBLIC SAFETY
HARVARD UNIVERSITY POLICE 617-49**5-1212**

CHEMICAL SPILLS OR GAS LEAKS
OPERATIONS CENTER 617-49**5-5560**

If Time Permits, Contact the Staff

John Sweeney – EHS 5-1290
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Contents

1 Emergency Response Checklist

IF A TOXIC GAS LEAK OCCURS

1. Push a Yellow “Emergency Gas Off” button
2. Evacuate the building immediately
3. Alert others on the way out
4. Meet outside in front of Pierce Hall

IF YOU HEAR THE FIRE ALARM

1. Evacuate the building immediately
2. Alert others on the way out
3. Meet outside in front of Pierce Hall

IF YOU SEE SOMEONE UNDER THE EMERGENCY SHOWER OR EYE WASH

1. If the victim is by themselves, stay close to assist.
2. Call 911 and demand an ambulance.
3. If requested, assist the person in removing contaminated clothing being careful not to become contaminated.
4. Advise person to stay in shower 5 minutes for HF contamination, 15 minutes for all other chemicals.
5. If the chemical is Hydrofluoric Acid (HF) assist the victim in applying Calgonate (calcium gluconate) while wearing clean gloves.
6. Get the MSDS sheet (from Fire Command Center or print from on-line) and hand it to the Emergency Response Team or fire department.
7. Notify a staff member or call the Operations Center at 617-49**5-5560**.

IF YOU GET CHEMICALS ON YOUR SKIN

1. Approach the nearest emergency shower or eye wash and pull the handle to activate.
2. Demand help but remain under the emergency shower or eye wash.

IF A FIRE STARTS

1. Pull fire alarm located at emergency exit doors (and if in cleanroom press the yellow Emergency Gas Off alarm).
2. Evacuate the building immediately.
3. Alert others on the way out.
4. Meet outside in front of Pierce Hall.

2 Responsibilities

2.1 CNS Management and Administration

2.1.1 Prior to access to CNS laboratories, ensure all employees, students, and/ outside users have been trained on this document.

2.1.2 Enforce the contents of this document in areas that you supervise.

2.1.3 Periodically review the contents of this document with the staff.

2.1.4 Administer the reading and recordkeeping of this Procedure for all CNS staff and all users assigned to work in the CNS areas.

2.2 LISE Health and Safety Officer

2.2.1 As the Safety Manual author, the LISE Health and Safety Officer reviews this Procedure periodically to ensure its continued effectiveness.

2.2.2 Serve as point of contact for any questions relating to this document or any other occupational safety and health concerns.

2.2.3 Enforce the contents of this document in areas that you supervise.

3 Purpose

3.1 Safety: ensure a safe working environment.

3.2 Success: promote successful laboratory operation, scientifically and educationally productive.

3.2.1 Successful laboratory operation relies on individual user's understanding, participation and self-discipline.

3.2.2 Everyone, whether faculty member, student user, or staff engineer, is equally important to the success of the protocol.

3.2.3 Successful operation is a shared responsibility among all users and staff members.

3.3 Satisfaction: communicate operational strategies that satisfy user's needs.

3.4 Awareness: Provide guidance and basic awareness. Prepare experimentalists for their future roles.

4 Scope

4.1 This manual is required reading for all employees and users of CNS laboratories.

4.2 This manual describes the safety hazards, engineering controls, and safety policies common to laboratories.

4.3 Study and mastery of the material in this procedure are obligatory but insufficient for laboratory access. Each laboratory and instrument also has dedicated training including additional safety detail.

5 Emergency & Personal Protective Equipment

5.1  MSDS (Material Safety Data Sheets)

5.1.1 Function: For determining chemical hazards and recommended precautions for use.

5.1.2 Use: Look up information on all chemicals prior to use.

5.1.3 Locations:

5.1.3.1 http://www.cns.fas.harvard.edu/safety/msds.php

5.1.3.2 Hard copies in the Fire Command Center LISE lobby.

5.2  Nitrile Gloves

5.2.1 Function: Protects cleanroom surfaces from contamination and offers wearer some splash protection against most chemicals.

5.2.2 Use: Don before entering cleanroom, Soft Materials Cleanroom (SMCR), North Materials Synthesis rooms G06 and G05. In other labs such as B15A (imaging sample prep room) required when handling chemicals. If you suspect chemical contamination replace gloves as soon as possible.

5.2.3 Location: At or near the entrances to each area.

5.3  Safety Glasses and/or Goggles

5.3.1 Function: Offers protection against objects that may injury your eye if projected and also offers some protection against chemicals.

5.3.2 Use: Always wear when entering wet laboratory handling liquid chemicals, and as instructed for each laboratory space.

5.3.3 Location: In gowning area and at entrances to lab spaces.

5.3.4 Oversized safety glasses can be used to place over prescription glasses

5.4    Acid Handling Personnel Protective Equipment (PPE)

5.4.1 Function: For personal protection against chemical splashes. The items are chemical resistant.

5.4.2 Use #1: **Always** wear the above PPE when handling **any** acid (including hydrogen peroxide and etchants like chromium etchants) or any strong base (ammonium hydroxide, potassium hydroxide, sodium hydroxide, etc).

5.4.3 **NOTE:** Contamination Prevention: Prior to use, wipe the outside and inside of the face shield window with a wet wipe. Dry the window with a dry wipe.
In addition, rinse yellow chemical gloves with DI water if you suspect they are contaminated and also before throwing them into the trash. Yellow chemical glove contains natural rubber which may contain allergens.

5.4.4 Location: By the wet benches.

5.5   Other Chemical Handling Personnel Protective Equipment (PPE)

5.5.1 Function: Protection from chemical contamination and possible projectiles.

5.5.2 Use: Wear face shield and nitrile gloves anytime substrates are spinning on spinners in the solvent spin benches.

5.5.3 Use: Wear face shield when pouring from any one gallon containers.

5.5.4 Location: At the Personal Protective Equipment racks near wet benches or fume hoods.

5.6  Cryo-gloves and Face shield for Liquid Nitrogen, liquid helium

5.6.1 Function: For personal protection against cryogenic liquid exposure.

5.6.2 Use: As a minimum a face shield and cryogenic approved gloves must be worn when transferring or any time there is a potential exposure to cryogenic liquid.

5.6.3 Location: Anywhere there is a transferring of cryogenic liquid from one vessel to another.

5.7 

Fire Alarm Enunciator and Strobe

5.7.1 Function: To alert building occupants of a fire or similar emergency requiring immediate evacuation.

5.7.2 Use: Upon alarm, evacuate building and proceed to nearest fire stairwell and report to rally point in front of Pierce Hall. Adhere to any instructions provided over the pubic address system (delivered from the fire command center at the LISE lobby). LISE fire alarms will activate on floor with emergency, floor above, and floor below.

5.7.3 Location: Throughout the building.

5.8 

Fire Alarm Pull Station

5.8.1 Function: To alert others of a fire in case the alarm does not start on its own. At solvent benches, pull station will also activate CO2 suppression system.

5.8.2 Use: Pull white T bar down.

5.8.3 Location: Fire alarm pulls are located in all labs, at each entrance to each fire stairwell, and at each solvent wet bench. Solvent bench pull station will ALSO activate CO2 suppression system at that bench.

5.9 

Emergency Gas Off (EGO) Station

5.9.1 Function: Part of the Toxic Gas Monitoring System. Used to activate the blue toxic gas alarm and the fire alarm and will also shut down (at the gas cabinet) all the toxic/flammable/corrosive gases.

5.9.2 Use: Lift cover and push in.

5.9.3 Location: At each exit from the following areas: cleanroom, G04, G05, G06, G12, G27, M14 gas bunker, and at loading dock exits.

5.10 
Toxic Gas Alarm Enunciator and Strobe

5.10.1 Function: To alert occupants of emergencies associated with toxic gases including chemical release or system problems such as exhaust failure.

5.10.2 Use: Listen to the alarm and find an emergency exit. Blue alarm means gas in breathing area. Leave building and report to an area in front of Pierce Hall. Yellow/amber alarm means gas leak in gas cabinet or tool exhaust or loss of cleanroom exhaust. When you hear it, leave immediate area and wait in any location where amber lights are not flashing until further notice. It will take some extended time for CNS staff to investigate alarm condition. Never enter any CNS room when either amber or blue lights are flashing.

5.10.3 Location: Throughout cleanroom and labs on ground level, the mezzanine level of LISE, LISE loading dock, LISE roof HVAC area, Science Center roof top, chiller plant roof top, and Science Center mail room.

5.10.4 Toxic gas use is only allowed non-holidays, Monday through Friday, between the hours of 6am and 8pm.

5.11  Fire Extinguishers

5.11.1 Function: Used to put out a small incipient fire.

5.11.2 Use: To be used by building occupants who have been trained in fire extinguisher training. Harvard EHS offers a fire extinguisher course from May to October every year.

5.11.3 Location: In main hallways and in each lab.

5.12  First Aid Kit

5.12.1 Function: Supplies for minor first aid.

5.12.2 Use: To be used to apply first aid to minor cuts. It is also a location of Calgonate (calcium gluconate gel) to be applied to hydrofluoric acid (HF) burns.

5.12.3 Location: At ground and basement floor elevator lobbies and in the cleanroom gowning area.

5.13 

"Calgonate" contains calcium gluconate

5.13.1 Function: To neutralize the fluorine ions as a result of a hydrofluoric (HF) acid exposure.

5.13.2 Use: Put on clean gloves and apply Calcium Gluconate to affected area of skin after some one has called 5-5560 and after affected area has been rinsed with water for 5 minutes. Rinse eyes for 15 minutes and DO NOT apply Calgonate to the eyes.

5.13.3 Location: At each wet bench that utilizes Hydrofluoric acid and at the first aid kit in the cleanroom gowning area.

5.14  Emergency Exits inside the cleanrooms or in other lab spaces

5.14.1 Function: To serve as the first means of egress from a lab or cleanroom.

5.14.2 Use: Occupants exit these large egress doors of laboratory during fire alarms and blue light toxic gas alarms and then find the nearest stairwell to leave building and then meet in front of Pierce Hall.

5.14.3 Location: See each lab for location. In the cleanroom there are six emergency exits - 3 on window (clean) side and 3 on the service chase side of cleanroom.

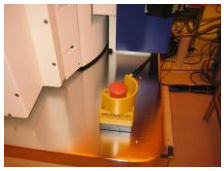
5.15 

Automatic External Defibrillator (AED)

5.15.1 Function: To revive someone if their heart stops beating.

5.15.2 Use: To be used by trained personnel. Instructions in kit.

5.15.3 Location: First floor, ground floor, and third floor elevator lobbies.

5.16  Emergency Machine/Mains Off (EMO) Button

5.16.1 Function: The red button on equipment is there to place the machine in a de-energized state during emergency situations.

5.16.2 Use: Find and push in the red button to place machine in de-energized state when equipment is smoking, shaking, leaking gas, or exhibiting any other emergency-related equipment failure.

5.16.3 Location: On most machines in cleanroom, G05, G06, B15A sample prep room, and in the imaging suites on some microscopes.

5.17  Emergency Showers and Eye Wash Stations

5.17.1 Function: For chemical decontamination of a person or their clothing.

5.17.2 Use: Remove contaminated clothing and pull stainless steel triangle and stay under shower for 15 minutes. If exposed to HF, use emergency shower for 5 minutes, then apply Calcium Gluconate. Water is warm.

5.17.3 If eye contamination, hold eyes open with hands and place eyes directly over the eye wash station for 15 minutes. Water is warm.

5.17.4 Location: There are six showers and eye wash stations in the cleanroom. Another is located in basement just outside B15A sample prep lab, and there is another in G06.

5.17.5 There is a modesty curtain attached to shower and a Tyvek suit attached to the wall. The Tyvek suit can be put on in place of contaminated clothing.

5.17.6 Most showers drain directly onto the floor.

Figure 1: Locations of safety showers and eye washes.

5.18 

Lock out Tags

5.18.1 Function: To notify people in an area that a piece of equipment is in shut down mode.

5.18.2 Use: Tag is attached to the equipment or its power source to inform affected employees (people not working on the piece of equipment but may desire to operate it) that a qualified mechanic is working on the equipment and equipment must not be energized nor operated.

5.18.3 Location: May be used anywhere in the building.

5.19 
Exhausted Fume Hood

5.19.1 Function: Exhausted enclosure to isolate personnel from chemical fumes or reactions.

5.19.2 Use: Fume hood exhaust must be functional and sash lowered to 18 inch mark or lower for isolation to be effective. Never put head in hood.

5.19.3 Location: There is one exhausted standard fume hood in B15A.

5.20 
Ductless Fume Hood

5.20.1 Function: Provides protection by drawing fumes into filter unit. Filtered air is returned to lab.

5.20.2 Use: Internal fan must be on for unit to be effective. Filter must be in place, appropriate for the hazard, and not be depleted.

5.20.3 Location: G06, G04

5.21 HEPA-filtered Enclosure

5.21.1 Function: Provides low particle environment by blowing filtered air downward onto sample.

5.21.2 Use: Sample protection from dirt. NO PROTECTION TO USER FROM FUMES (gases and vapors)! ALL FUMES BLOWN INTO ROOM!

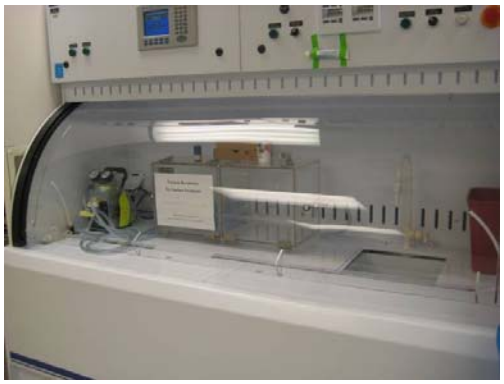
5.21.3 Location: G06

5.22 Bio Hood (biosafety cabinet)

5.22.1 Function: Exhausted chemical work benches which provide protection from fumes. Also provide UV sterilization.

5.22.2 Use: Exhaust system must be functional and sash lowered to provide protection. Do not attempt to use hood during UV clean process.

5.22.3 Location: Two bio hoods in G05.



5.23 Acid Wet Bench

5.23.1 Function: Exhausted enclosure, similar to fume hood but with slanted sash design. White plastic provides limited acid resistance against spills.

5.23.2 Use: Exhaust must be operational during use (system will alarm if exhaust insufficient). Training required.

5.23.3 Location: G06 and G07 (cleanroom).

5.24  Solvent Wet Bench

5.24.1 Function: Exhausted enclosure, similar to fume hood but with slanted sash design. Polished steel provides limited solvent resistance against spills.

5.24.2 Use: Exhaust must be operational during use (system will alarm if exhaust insufficient). Training required.

5.24.3 Location: G06 and G07 (cleanroom).

5.25 Video System

5.25.1 All CNS main laboratory spaces have video cameras and recorders.

5.25.2 Used for remote monitoring during emergency.

5.25.3 Used to investigate safety incidents.

6 General Safety Requirements

6.1 Report any work injury to the CNS administration and the LISE Health and Safety Officer.

6.2 Obey all warning signs, labels, and tags.

6.3 Personal Protective Equipment (PPE) must be worn where required.

6.4 No hazardous work may be conducted alone (buddy system).

6.5 Keep aisles, stairways, exits, and safety shower/eye wash stations unobstructed at all times. Do not store or move equipment into these areas.

6.6 Know the location of emergency and safety equipment in your area. This includes PPE, safety shower/eye wash, first-aid kits, emergency exits.

6.7 Use portable fire extinguishers only if you have been trained to operate them.

6.8 Observe no smoking signs throughout the facility.

6.9 Eating and drinking in areas where chemicals are used is prohibited.

6.10 Horseplay, scuffling, and other acts which tend to have an adverse influence on the safety or well-being of employees and lab users are prohibited.

6.11 Report defective equipment and unsafe conditions immediately to the CNS staff so they may be corrected promptly.

6.12 Damaged tools or equipment shall be removed from service and tagged to prevent use.

6.13 Notify Harvard Operations Center of emergency conditions by dialing "**5-5560"**. Operations center will summon the LISE Emergency Response Team (ERT) and off-site emergency response crews, as necessary, based on the severity of the emergency event.

6.14 Only authorized persons shall operate machinery, equipment, or tools. Only perform operations for which you have been trained.

6.15 Do not operate tools or other machinery that is missing or has defeated safety protective devices such as guards, alarms, interlocks, local exhaust ventilation, etc. Notify CNS staff of any deficiencies.

6.16 Machinery, equipment, tools shall not be serviced, repaired, or adjusted by anyone other than the CNS staff. CNS staff will follow the appropriate hazardous energy control procedures to safely work on such equipment.

7 Discipline

7.1 All users and occupants of CNS laboratory must follow all safety requirements and must conduct themselves in a way which does not endanger health or equipment integrity.

7.2 Anyone who violates safety policy or endangers health or equipment integrity is subject to discipline including loss of laboratory access. Minor (non-life threatening) violations will typically be subject to the following escalating disciplinary schedule

7.2.1 First offense: Written warning to user and advisor. User may be required to repeat training.

7.2.2 Second offense: Loss of laboratory access for 5 days. Written warning to user and advisor. User may be required to repeat training.

7.2.3 Third offense: Loss of laboratory access for 30 days. Written warning to user and advisor. User may be required to repeat training.

7.3 Major and life-threatening offenses will result in immediate loss of laboratory access, with review and final fate determined by the CNS Director.

8 Laboratory Access

8.1 Only users who have achieved all required room certifications may enter any CNS lab.

8.2 For any room which requires swipe card or iris scan access, user may only enter the room after swipe of own card or scan of own eye. HOLDING DOORS FOR OTHERS TO ENTER, OR SHARING SWIPE CARD WILL RESULT IN DISCIPLINARY ACTION.

8.3 Only staff members may bring uncertified users into any laboratory space.

9 Telephones

9.1 Most CNS labs have campus-only phones. These phones are capable of calling 911 and on-campus 5-digit numbers. For phones with off-campus access, dial 9+number except for 911 (no leading 9) for emergencies.

9.2 Never handle a telephone with contaminated hands or gloves.

9.3 Personal cell phones are allowed in CNS laboratories. Cell phone use is not allowed during hazardous activity. Use of headphones/earbuds is not allowed. Photography on the Harvard campus requires University permission.
No MP3 Players or other headsets allowed.

9.4 When using telephone be respectful of those around you. Make phones immediately available in case of emergency.

9.5 LISE is equipped with repeaters for Verizon service. Other services may provide poor reception in lower levels.

10 Personal Protective Equipment (PPE) Summary

10.1 Wet Chemistry PPE Requirements are listed in the table below per lab area:

Area	Type of Hood	PPE Requirements	Chemicals
Wet Process Bay Cleanroom	White Plastic Acid Wet Bench	• Safety Glasses / Safety Goggles • Face Shield required at all times while working at these two acid benches. • Blue Apron • Yellow Chemical gloves over the white nitrile • **When handling 25% TMAH wear**: Two pair of yellow chemical gloves or one pair of yellow 20 ml Trionic E194 MAPA gloves over nitrile gloves.	Various Acids (HF, Nitric, Sulfuric etc) and Strong Bases (Any Hydroxide Solutions etc). 25% Tetra-methyl ammonium hydroxide (TMAH)
Wet Process Bay Cleanroom	Stainless Steel Solvent Wet Benches	• Safety Glasses / Safety Goggles • Face shield must be worn when pouring from any one gallon container and when spinner is in operation. • Standard White Nitrile (change when contaminated)	IPA, Acetone, Methanol, n-methyl pyrolidinone (PG Remover, Baker PRS 3000), propylene glycol monomethyl ether acetate,
Photo Lithography Bay Cleanroom	Stainless Steel and White Plastic Wet Benches	• Safety Glasses / Safety Goggles • Face Shield when pouring from any one gallon container and when spinner is in operation. • Standard White Nitrile (change when contaminated) • **When working with chemicals that contain TMAH wear**: Safety glasses and two pair of yellow chemical gloves or one pair of 20ml Trionic E194 MAPA gloves over nitrile gloves.	MIF Developers, CD26, CD 30, IPA, Methanol, Acetone TMAH containing: CD26, MIF 319 Developer, 300 MIF Developer, 726 MIF Developer.
Any Spinner Benches	Stainless Steel Wet Benches	• Safety Glasses / Safety Goggles • Face Shield- when substrates are spinning and when pouring from any one gallon container. • Standard White Nitrile	Photoresists and spinning substrates
E-beam Lithography Bay Cleanroom	Stainless Steel Wet Benches	• Safety Glasses / Safety Goggles • Face Shield- when pouring from any one gallon container and when spinner is in operation. • Standard White Nitrile	Photoresists
North Materials Synthesis G06	Stainless Steel Wet Benches	• Safety Glasses / Safety Goggles • Face Shield- when pouring from any one gallon container or when substrates are spinning on	Solvents

		spinner. • Standard White Nitrile • White Tyvek lab coat	
North Materials Synthesis G06	White Plastic Wet Benches	• Safety Glasses / Safety Goggles • Face Shield when working with acids and strong bases. • Blue Apron • Yellow Chemical gloves over the white nitrile	Various Acids (Hydrofluoric, Nitric, Sulfuric etc) and Strong Bases (Any Hydroxide Solutions etc)

North Material Synthesis G06	Nano High Efficiency Particulate Air filter hood	• Safety Glasses / Safety Goggles • Face shield when pouring from any one gallon container. • White Lab coat • Standard White Nitrile	Nanoparticles (dry and in solution).
North Materials Synthesis G05 bio room	Bio Hoods (Biosafety Cabinets)	• Safety Glasses/safety goggles • White Nitrile gloves • Lab coat	
Imaging Sample Prep B15A	Chemical Fume hood	• Safety Glasses / Safety Goggles • Face Shield when pouring from any one gallon container. • Standard White Nitrile gloves	Solvents
All Areas of CNS	LN2 dewars	Face shield and cryo-gloves	Liquid Nitrogen

10.2 Inspect PPE before each use. If damaged, contaminated, or breakthrough is suspected, discard it and obtain new PPE. Rinse gloves with DI water before disposal if contaminated.

10.3 Safety glasses are required in all CNS labs when working at wet benches. If you wear prescription safety glasses you must place oversized safety glasses over your prescription glasses any time working at **any** wet bench.

10.4 Footwear: Open toed or open heel shoes and sandals are not allowed in any CNS laboratories.

10.5 Maintain PPE free of chemical residues. Rinse and dry-off chemicals spilled onto gloves and face shields. If apron becomes contaminated wipe off chemical with wet wipe and then dispose of it in the waste receptacle.

10.6 Do not leave gloves unattended on top of wet benches, chemical dispense cabinets, floor, equipment, or other work surfaces.

10.7 Dispose of chemical gloves in the appropriate debris can at the end of each day or whenever they become contaminated. Before disposing, always rinse gloves.

10.8 Chemical apron coats (blue) and face shields shall be clean and stored on the available hooks within the PPE storage cabinet or at the point of use.

10.9 Blue Apron Sizes: Depending on the manufacturer, the size of the PVC coat apron can be determined by where you got them in the PPE bin. The bins should be labeled Small, Regular and Large.

10.10 The sequence to don (put on) & doff (remove) chemical personal protective equipment is as follows:

10.10.1 **Don sequence**:

10.10.1.1 Apron

10.10.1.2 Face shield

10.10.1.3 Outer gloves

10.10.2 **Doff (Removal) sequence**:

10.10.2.1 Outer gloves

10.10.2.2 Face shield

10.10.2.3 Apron

11 Material Safety Data Sheets

11.1 Material Safety Data Sheets (MSDS) are available for all hazardous substances approved for use in CNS laboratories. MSDS's for all manufacturing-related chemicals and gases are available online on the CNS website under the Safety Section. Hard copies are maintained at the Fire Command Center at entrance to LISE/McKay.

11.2 If you have trouble locating a MSDS, contact LISE Health and Safety Officer at 495-1290 or any one on the CNS staff.

12 Chemical Safety Rules

12.1 CNS laboratories use a number of chemicals including acids, bases, solvents, oxidizers, and compressed gases. These hazardous materials pose both physical and chemical hazards to personnel. To minimize such hazards to employees, engineering control methods are utilized to the extent possible where hazardous materials are used. Strict adherence to established work methods and donning of personal protective equipment provides additional control measures to prevent individual exposure to these hazardous materials.

12.2 New Materials Request

12.2.1 Before any new material (biological, chemical, nanoparticle, or solid material to be grinded) is brought into the CNS facility the "Material Request Form FM006 must completed and sent to CNS Administration in room 306 for EHS approval. This form is located on the CNS website.

12.3 Chemical Storage

12.3.1 Store chemicals in the proper chemical storage cabinet. There are two types of chemical storage cabinets located in CNS laboratories: Blue for acids and bases, and Yellow for flammables. Verify proper storage area for any chemical with laboratory staff.

12.3.2 **Acids** -- Chemicals with a low pH. Corrosive to skin and eyes. Some have strong vapors. Stored under white acid wet benches or in **Blue** cabinets located in chases or in blue corrosive cabinets in other CNS lab spaces outside the cleanroom.

12.3.3 **Bases** -- Chemicals with a high pH. Corrosive to skin and eyes. Some have strong vapors. Stored under white acid wet benches or in **Blue** cabinet. Must be stored in a separate secondary container if stored in same cabinet as acids.

12.3.4 **Solvents/Flammable** -- Materials that burn. Irritating to eyes and skin. Most have strong vapors. Stored under steel solvent wet benches or in **Yellow** cabinet. No storage of flammable liquids in the basement areas of LISE is allowed. Only a limited amount of squirt bottles is allowed in the basement areas and only in fume hood.

12.3.5 **Oxidizers** -- Materials that oxidize. Corrosive to skin and eyes. Some with vapors. Oxidizers will be stored in the blue cabinet with acids. Nitric acid must be stored in its own secondary container. It is an oxidizer and a strong acid.

12.3.6 Acids, bases, and flammables must be stored separately. Oxidizers must **not** be stored with flammables. Abide by the general safety rules as posted on each chemical storage cabinet.

12.3.7 **In the Cleanroom:** A chemical supply vendor and/or CNS staff stocks chemical storage cabinets to ensure chemical compatibility. It is essential that chemical bottles (full, empty, or partially full) are returned to the same storage cabinet to ensure that incompatible chemicals are not stored together.

12.3.8 **In the basement lab or the surrounding ground floor labs:** CNS staff will stock these cabinets.

12.3.9 Tightly cap and store all chemical bottles in designated storage cabinets until ready to use.

12.3.10 Keep all storage cabinets closed and handles latched when not in use.

12.3.11 Squeeze bottles may be used on for the following chemicals, and only in labeled containers: water, methanol, IPA, acetone and Propylene glycol methyl ethyl acetate (PGMEA). Squeeze bottles with flammable materials must be stored in a vented chemical hood. Be aware that squeeze bottles can leak significant amounts as a result of pressure of temperature change; do not store near ignition source.

12.4 Chemical Labeling

12.4.1 All chemical containers must be labeled with the identity of the material and the physical health hazards presented by the material. If a container is not labeled, do not handle it. Notify the CNS staff immediately when an un-labeled container is found.

12.4.1.1 Label must include full chemical name.

12.4.2 When labeling beakers make sure you use chemical name and contact information (this includes user name, date of experiment, user telephone number) on the beaker or on a wipe placed in front of the container.

12.4.3 Always read the label of a chemical container before handling.

12.5 Chemical Transportation

12.5.1 Carry only one chemical bottle per hand at a time to prevent bodily injury due to strain and to prevent a chemical spill due to dropping of the bottle(s). Always use the handle or carry pail to carry the bottle. Use the available chemical transportation cart when moving multiple bottles of chemicals.

12.5.2 Corrosive chemicals in glass bottles (i.e., Nitric Acid, Etchants, Resists and some developers) must be transported using the available rubber or plastic bottle carriers if leaving wet bench area.

12.5.3 Do not transport chemical containers unless the caps are tight.

12.6 Chemical Use

12.6.1 All chemicals must be handled in wet benches or in some exhausted enclosure.

12.6.2 Chemicals are to be handled and mixed only by personnel who are authorized and are wearing the appropriate personal protective equipment.

12.6.3 Open chemical containers cautiously. Point the top of the container away from your face and body. Pressure may have developed inside the containers during transport.

12.6.4 When pouring chemicals, pour slowly in a controlled manner to avoid splashing.

12.6.5 After pouring chemicals from bottles, wipe the neck of the bottle clean to prevent the chemical from dripping down the side of the bottle and damaging work surfaces or personnel.

12.6.6 “Always Add Acid” **(AAA)** to water, never the reverse.

12.6.7 Do not mix a solvent with an acid or mix an acid and a base. Solvents and oxidizers must never be stored or mixed. These chemical groups are incompatible and can react violently.

12.6.8 Immediately clean up chemical residues on work surfaces. Clean up with wipes and place in appropriate waste debris cans located in the wet benches.

12.6.9 When bottles are completed they must be properly cleaned and disposed of. Details will be provided during laboratory room orientation.

12.6.10 To reduce possibility of fire or explosion chemicals can only be heated to less than 10 degrees of flash point of that chemical (Class I liquids-flashpoints below 73F can never be heated on hot plates---acetone, Isopropyl alcohol, MIBK/IPA etc)

13 Physical and Health Hazards of Chemicals

13.1 **Carcinogen**: Carcinogens are materials that are known or suspected of causing cancer after repeated exposure over a long period of time. Examples include: Inorganic arsenic, chloroform, formaldehyde, hexavalent chromium, asbestos, diesel exhaust and tobacco smoke. Trichloroethylene is a suspect carcinogen.

13.2 **Combustible**: A material that is capable of burning and will ignite only if heated. The temperature necessary before a fire could be started is called the flash point. Examples include: Photoresists and N-Methyl-2-Pyrollidone (NMP).

13.3 **Corrosive**: Corrosives cause permanent damage or burns to the eyes, skin, or mucous membranes such as the inside of the nose or mouth. Examples include: hydrofluoric acid, ammonium hydroxide, developers (CD-30, MIF 400), acetic acid, buffered oxide etch (BOE), phosphoric acid, nitric acid, and gold etchant.

13.4 **Irritants**: Irritants cause a reversible inflammation of the eyes, skin, or mucous membranes such as the inside of the nose or mouth. Examples include: photoresists, isopropyl alcohol, acetone, and many more.

13.5 **Flammable**: A flammable material is capable of burning and will readily ignite at room temperature. Examples include: acetone, isopropyl alcohol, hexamethyldisilazane (HMDS), hydrogen gas, n-butyl acetate.

13.6 **Oxidizer**: Oxidizers are materials that readily yield oxygen or other oxidizing gas, or that readily react to promote or initiate combustion of combustible materials. Examples include: hydrogen peroxide, chlorine gas, oxygen, nitrous oxide gas, and nitric acid.

13.7 **Pyrophoric**: Pyrophorics are materials that will spontaneously ignite in air at or below a temperature of 130 F. They do not need an ignition source like a flammable or a combustible material. Examples of pyrophorics: silane gas and diborane gas.

13.8 **Reproductive Toxin**: Reproductive toxins are materials that can affect the ability to reproduce or can cause birth defects in offspring. Examples include: n-Methylpyrrolidone (NMP is found in Remover PG, PRS 3000 Resist Stripper, and Microposit Remover 1165), lead, and carbon monoxide.

13.9 **Sensitizer**: Sensitizers can cause an allergic reaction in a sensitive individual. Typically this reaction would be after repeated exposure. Examples: nickel and gold may cause sensitization upon contact with skin.

13.10 **Target Organ Effects**: Target organ effects is a general term which applies to a wide variety of potential health affects where a material can affect a certain part of the body. Target organ effects can potentially cover any body system including the lungs, liver, kidney, blood, or central nervous system. Examples include: All hazardous chemicals have an effect on some system of the body.

13.11 **Toxic**: Toxic materials are potentially poisonous at low levels of exposure. Highly toxic materials are potentially poisonous at extremely low levels of exposure. Examples include: chlorine gas, diborane gas, phosphine gas, hydrofluoric acid.

13.12 **Unstable**: Unstable materials are capable of dangerous reaction, even explosion, caused by excessive heat or pressure.

13.13 **Water Reactive**: Water reactive materials are capable of a dangerous reaction when exposed to or mixed with water. Examples include: hexamethyldisilazane (HMDS).

14 Chemical Warning Properties

14.1 Most chemicals in use in CNS labs have physical properties that alert a person to their presence such as taste, odor, or irritation. Typically, a chemical will be noticed long before it is present at a concentration that is potentially harmful. These chemicals are said to have good warning properties since a person can readily detect the chemical before it is present at a hazardous level.

14.2 Some chemicals can be present at levels that are potentially harmful, but lack properties that warn of their presence. These chemicals are said to have poor warning properties since a person could be exposed at potentially harmful levels without any warning. In these cases, continuous chemical detection systems are used that alert a person to the presence of the chemical at potentially hazardous levels.

15 Chemical Hazard Classes

15.1 **Acids**: Acids are corrosive to skin and eyes causing serious burns. Generally the effect is very quick with the exception of hydrofluoric acid which has a delayed effect. Most acids give off corrosive vapors. Examples of acids are acetic, hydrochloric, hydrofluoric, nitric, phosphoric, 10:1 buffered oxide etch (BOE).

15.2 **Bases**: Bases (also called alkali or caustic) are corrosive to skin and eyes causing serious burns. Bases are especially hazardous to the eyes causing permanent damage. Generally the effect is relatively slow starting as a slippery feeling on the skin. Examples of bases are ammonium hydroxide, sodium hydroxide, and tetra methyl ammonium hydroxide (TMAH) found in certain photoresist developers (CD 30, MIF developers).

15.3 **Oxidizers**: A material that can start or increase a fire by donating oxygen. They can also cause severe skin or eye irritation or even burns. Examples of oxidizers: hydrogen peroxide, oxygen gas, nitric acid.

15.4 **Solvents**: Solvents are liquids used to dissolve other materials. They are typically irritating to skin and eyes and give off strong vapors. Inhalation can cause headaches or dizziness. Most solvents are flammable or combustible liquids. Examples of solvents are acetone, isopropyl alcohol, hexamethyldisilazane (HMDS), n-butyl acetate, n-Methylpyrrolidone (NMP) and photoresists.

16 Compressed Gases

16.1 Compressed gases are all hazardous due to their storage pressure. Most can cause suffocation in the event of a large release in a confined area. Compressed gases can be “inert” presenting very little, if any, health hazard or they can have a variety of hazards including flammable, corrosive, pyrophoric, oxidizing, or toxic. Examples of compressed gases are ammonia, argon, boron trichloride, silane, forming gas (hydrogen-nitrogen mixture), freons, hydrogen, nitrogen, and silicon tetrafluoride.

16.2 The gases used within the facility for processing are generally supplied under high pressure from steel compressed gas cylinders. In most cases, these cylinders are housed in special gas cabinets and fitted with a variety of high purity valves, regulators and flow control devices. Gas cylinders must be treated with respect in all cases. An enormous amount of energy is stored in the compressed gas. In addition, many of these gases are toxic, or at least severely corrosive.

16.3 Compressed Gas Hazards

16.3.1 Before using a tool that utilizes compressed gas or cryogenic liquid, read the appropriate Material Safety Data Sheet and understand the properties of the product and the precautions to be taken.

16.3.2 Primary hazards associated with compressed gases and cryogenic liquids include asphyxiation, fire/explosion, chemical burns, chemical poisoning, cold burns, high pressure, and sprains/strains/falls/bruises/broken bones due to improper handling.

16.3.3 Compressed gases fall into many different hazard classes. Gases can fall into more than one hazard class. Hazard classes and examples of gases used at the LISE CNS facility are as follows:

16.3.3.1 **Inert / Simple Asphyxiant** such as argon, helium, nitrogen and sulfur hexafluoride.

16.3.3.2 **Corrosive** such as ammonia, boron trichloride, chlorine, hydrogen bromide.

16.3.3.3 **Toxic** such as chlorine, boron trichloride.

16.3.3.4 **Highly Toxic** such as diborane, phosphine.

16.3.3.5 **Flammable** such as hydrogen and methane.

16.3.3.6 **Pyrophoric** such as silane (it spontaneously ignites in air at concentrations between 4% and approximately 90%).

16.3.3.7 **Oxidizing** such as chlorine, nitrous oxide, oxygen.

16.4 Cylinder Handling

16.4.1 Only CNS staff are permitted to change gas cylinders.

16.4.2 All cylinders must be properly labeled and the contents identified.

16.4.3 Separate full and empty cylinders.

16.4.4 Arrange full cylinders so that old stock is used first.

16.4.5 Cylinders considered empty should be labeled EMPTY.

16.4.6 Always store cylinders (full or empty) in their upright position and secured to prevent tipping.

16.4.7 Do not drop cylinders or permit them to strike each other. Never subject cylinders to abnormal mechanical shocks that may cause damage to their valves or pressure relief devices.

16.4.8 Never drag, drop, roll or slide cylinders. Cylinders shall be moved using a suitable hand truck.

16.4.9 When not in use, the cylinder valve shall be closed, the regulator removed, and the valve protection cap installed.

16.4.10 Use only regulator compatible with the cylinder and gas. Mismatches can be dangerous!

16.4.11 A regulator should be attached to a cylinder without forcing the threads. A poor fit indicates that the regulator is not the proper one.

16.4.12 Faulty or leaky cylinders should be labeled and removed from the working area by trained personnel only and reported immediately to the Emergency Response Team (ERT) at LISE. Call 5-5560.

17 Incompatible Chemicals

17.1 Below find a PARTIAL listing of chemical incompatibilities. If unsure about compatibility, ask before mixing.

Chemical	**Chemical Incompatible with:**
Acetic Acid	Nitric acid, propylene glycols, peroxides, and permanganates
Ferric Chloride	Aluminum
Hydrogen Peroxide	Copper, chromium, iron, alcohols, acetone, organics
Mercury	Ammonia
Nitric Acid	Photo-resists developers, acetic acid, flammable liquids, flammable gases
All Acids	All bases (potassium cyanide, potassium hydroxide, sodium hydroxide, ammonium hydroxide etc)
Oxidizers (Permanganates, inorganic peroxides, persulfates, perchlorates)	Flammable liquids, organic materials, reducing agents (ex zinc, alkaline metals, formic acid)
Water Reactives (sodium, potassium, metal hydrides, hydrolysable halides)	Water
Nano-Strip	Solvents
Sulfuric Acid	Solvents

18 Specific HIGH Hazard Chemical Information

18.1 Refer to Material Safety Data Sheets for specific Hazards for each chemical. However, since Hydrofluoric Acid and others can be so toxic and used extensively that we will expound on the hazards.

18.2 **Hydrofluoric Acid, 48% (aka HF)**: Corrosive to eyes, skin, and mucous membranes. Vapors are severely irritating or corrosive. Toxic if swallowed. Corrosive effect can be delayed for several hours. Prolonged contact may cause bone damage. If contacted, rinse with water for five minutes and massage Calgonate gel onto affected area. Seek medical attention.

18.2.1 Buffered Oxide Etch (BOE) contains 5 to 10% hydrofluoric acid. Ammonium fluoride exposures should also be treated as an Hydrofluoric acid burn.

18.2.2 Hydrofluoric acid (HF) looks like water and can be mistaken as harmless. If you suspect that the liquid is HF treat it as HF.

18.2.3 Concentrated HF is considered "extremely" toxic (4, on the health hazard scale of 0-4). However, any solution containing a source of free fluorine ions is also hazardous. A concentrated ammonium fluoride solution is considered "very" toxic (3, on the health hazard scale), yet becomes "extremely" toxic when made more acidic, such as in the BOE (buffered oxide etch) mixtures we use at CNS. So, even though 20:1 BOE has much less HF (about 7% of volume) than 49% HF, because it also has about 38% NH4F and it is acidic, it presents the same toxic hazards as 49% HF.

18.2.4 On contact, HF easily passes through skin and tissue. Because its action can be delayed for many hours, it can distribute throughout the body.

18.2.5 Negatively charged fluorine ions bind very easily to positively charged calcium and magnesium ions to form insoluble salts (CaF2 and MgF2 salts form some natural gemstones.) In the body, Ca and Mg ions are used to mediate a variety of physiological processes, such as muscle movement and heart function. Calcium is also a chief component in bone.

18.2.6 Local tissue damage (at the area of contact) results from free hydrogen ions which cause corrosive chemical burns, and free fluorine ions which cause deep tissue damage including erosion of bone.

18.2.7 Systemic damage can occur when fluorine becomes distributed throughout the body. These conditions include POTENTIALLY FATAL electrolyte imbalances such as hypocalcemia (too little calcium) and hyperkalemia (too much potassium). Since calcium and potassium regulate the heart beat, irregular beating and cardiac arrest are manifestations.

18.2.8 Deaths have been reported from concentrated acid burns to as little as 2.5% BSA [body surface area exposed to HF]. For reference, this is roughly equivalent to the area of the FRONT AND BACK OF ONE HAND.

18.2.9 Calcium gluconate is used as an antidote. This provides extra calcium ions which can scavenge free fluorine ions before they penetrate and damage tissue. In cases of skin contact, calcium gluconate gel must be applied immediately to the area of contact.

18.2.10 Pure hydrogen fluoride is an extremely toxic gas which very easily dissolves in water. "Hydrofluoric acid" describes this solution form. HF easily passes between gas and liquid phases; so HF- (and NH4F-) containing solutions will emit toxic fumes. Although CNS

lab safety precautions tend to emphasize protection against skin contact with fluoride-containing solutions, remember to avoid inhalation of the fumes by always working under fully exhausted areas of the wet benches. And DON'T put your HEAD inside the bench.

18.2.11 Do not use glass containers to store HF in. Use only plastic containers. HF etches glass.

18.3 **25% Tetra-methyl ammonium hydroxide (25% TMAH):** 25% TMAH is a highly toxic chemical which can cause 2nd and 3rd degree burns to skin and is readily absorbed through the skin. Skin exposure covering >7% body surface area can be lethal in spite decontamination efforts.

Personal protective equipment (PPE) requirement:
Safety goggles, face shield, blue apron, two pair of yellow chemical gloves or one pair of the yellow 20 ml MAPA E194 Trionic glove over the nitrile gloves.

If >7% of your body surface area is contaminated with this chemical it could be lethal. Use extreme caution when working with 25% TMAH.

Avoid heating TMAH. This will only quicken the toxic effects.

All chemicals containing > 2% TMAH will have the following label on it:

Danger-TMAH
Contains > 2% Tetra-methyl-ammonium hydroxide
Potentially fatal following skin or inhalation exposure

18.4 **2.5% Tetra-methyl ammonium hydroxide:** Is found in the following chemicals at CNS:
MF CD-26 Developer, MF 319 Developer, 300 MIF Developer, 726 MIF Developer.
Even though these chemicals contain only 2.5% TMAH they must be handled with extreme caution. This concentration may not be lethal but it is still toxic and readily absorbed through the skin as a result the following PPE is required: safety glasses and two pair of yellow chemical gloves or one pair of the 20 ml yellow Trionic E194 MAPA gloves over the nitrile glove.

18.5 **N-Methylpyrrolidone (NMP)**: Combustible liquid. Can be readily absorbed through the skin. Can cause severe eye irritation. Repeated or prolonged contact can cause skin irritation. Strong solvent odor. Use two pair of nitrile gloves when handling. NMP is listed as a reproductive toxin under Proposition 65. NMP has been identified by the State of California to cause birth defects or other reproductive harm. Remover PG 1165 and Baker PRS 3000 and AZ 400T Photoresist Developer contain this chemical.

18.6 **Diborane Gas:** has a repulsively sweet odor and is used to deposit boron onto substrates using chemical vapor deposition tools. It is highly toxic and can ignite spontaneously in moist air.

18.7 **Phospine Gas**: has a dead fish odor and is used to deposit phosphorous onto substrates using chemical vapor deposition tools. It is highly toxic and can form explosive mixtures in air and can self-ignite.

18.8 **Silane Gas** can ignite spontaneously upon contact with air. It is can accumulate in certain areas and then explode. The gas is very unpredictable and it is stored and distributed to cleanroom from the LISE loading dock gas storage room M14.

18.9 **Piranha Etch:** Is a common name applied to a mixture of Hydrogen Peroxide and Sulfuric (typically 1:5). Piranha is extremely aggressive toward organic materials such as flesh and photoresist residue. It also removes heavy metal contamination. It is difficult to dispose of this mixture as the waste continues to react and decompose for a long period of time. This continuing reaction can build up pressure in closed containers, eventually causing them to burst. Also, if the solution is mixed very peroxide rich, unstable compounds may be formed. Therefore, Piranha is not allowed to be stored in closed containers. Nanostrip is a commercial stabilized version of Piranha Etch and is a recommended substitute.

18.10 Pregnancy: Users who believe themselves to be pregnant should discuss laboratory use with the Safety Officer as soon as possible. This need not severely restrict laboratory use but should nonetheless be discussed.

19 Hazardous Waste Management

19.1 Environmental Perspective

19.1.1 Work to minimize unnecessary release of chemical into environment

19.1.2 Use sparingly – only as much as you need

19.1.2.1 Solvents !

19.1.2.2 Photoresist !

19.1.3 Keep covered except when in use to avoid excess evaporation

19.1.4 Reference the chemical restriction signs on each wet bench.

19.2 Solvent Wet Benches contain a five gallon stainless steel metal container in the cabinet below. The metal containers are directly under each cup sink. Only solvents can be used in these stainless steel wet benches and only solvents can be poured down these cup sinks into the metal waste containers.

19.3 Halogenated solvents like Trichloroethylene, Methylene Chloride or bromobenzene can not be poured down any cup sink but must be collected separately in a one gallon waste container and labeled with a hazardous waste label.

19.4 Spinner Wet Benches are used for photoresist liquids only and only photoresist chemical can be poured down the cup sink in the spinner hoods.

19.5 Dedicated Developer hoods using chemicals such as CD30 and CD26, AZ MIF 726 Developer, AZ MIF 400 Developer have aspirators on the bench. Aspirators are not to be used for regular disposal operations. They will only be used for large built-in chemical bathes, which are covered in RCA clean training. Basic solutions will be disposed of in accordance with the latest revision of SOP019“Wet Bench Safety”. BTS 220 and SU8 Developers must be disposed of in solvent benches. Disposal of basic solutions like developers must be disposed of in accordance with SOP019 “Wet Bench Safety”.

19.6 Acid Wet Benches are used for etching and handling caustic liquids. Refer to the chemical restriction chart on the outside of the wet bench. The acid solutions, once spent will be disposed of in accordance with the latest revision of SOP019 Wet Bench Safety.

19.7 See picture below for appropriate label and storage:

Figure 2: Waste storage.

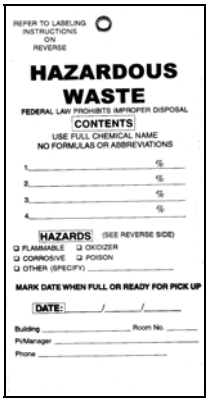


Figure 3: Waste label.

19.8 Gallium Arsenide wafers must be disposed of in a separate container - a white five gallon container marked with the words “Gallium Arsenide Wafer Waste Only”.

19.9 Broken Glass and Silicon wafers must be disposed of in a similar white five gallon container and it is marked with appropriate signage. This waste stream is not considered hazardous.

19.10 Razors, scalpels and syringes must be disposed of in red biohazard sharps containers.

Figure 4: Sharps collection container.

20 Chemical Spill

20.1 A release of hazardous materials to the environment (air, groundwater, loading dock drains, soil) shall be reported immediately to 5-5560. Operations Center will notify the CNS Emergency Response Team (ERT) and the Harvard EHS emergency on-call person who will try to stop and contain the release.

20.2 Procedure for spills outside of a Wet Bench or any vented enclosure:

20.2.1 Evacuate spill area and prevent others from entering.

20.2.2 Contact any CNS staff and **call 5-5560.**

20.2.3 Utilize the A-frame "Chemical Spill Keep Away" signs. They are located near spill supplies.

20.2.4 Remain clear of spill area, but stand by to warn others of potential hazards until CNS Emergency Response Team members arrive.

20.2.5 If directed to evacuate by CNS staff or EHS, proceed directly to the gown room by normal fab routes and stand by for further instructions.

20.2.6 If normal route to the gown room is blocked, exit fab through nearest exit and meet just outside the gowning area.

20.2.7 Be prepared to provide helpful information to emergency responders, including knowledge of injuries, missing persons, nature of spilled chemical, and activities leading up to the spill.

20.3 Procedure for spills inside a wet bench or fume hood or any other type of vented enclosure:

20.3.1 Small (incidental) spills and drips at work stations can be cleaned up by users wearing the appropriate personal protective equipment.

20.3.1.1 **Exception:** Never pick up a **Hydrofluoric acid** spill unless it is a dilute solution (<5%) and less than 50 ml. Otherwise call CNS staff and 5-5560.

20.3.2 Spills less than < ¼-gallon, CNS users wearing chemical gloves, apron, and face shield can use available absorbent pads to clean up the spilled liquid. Place contaminated wipes, gloves, etc. into a hazardous waste bag found in the yellow spill supply bucket. Make sure it is labeled as a hazardous waste and date it and place inside a wet bench. Contact CNS staff to report incident.

20.4 If at anytime a CNS user is uncomfortable or uncertain regarding the spill clean up, call 5-5560 and/or a CNS staff to activate Emergency Response Team for assistance.

20.5 Spills > ¼-gallon, call 5-5560 to activate CNS/EHS ERT for spill response.

20.6 Spill kits are available in most labs. In the cleanroom these kits can be found in yellow 5 gallon containers labeled "Spill Kits". The kits will be in the main corridor of cleanroom and in each wet lab. There will be an Acid spill kit, a Base spill kit, and general wipes for solvent spills.

20.7 Make sure waste is disposed of in a solid container and labeled as hazardous waste.

Figure 5: Contents of chemical spill kit.

20.8 Nanoparticle Waste:

20.8.1 Any solid nanoparticle waste must be collected in waste receptacles labeled as “Contains nano-waste”. Not all nano-waste is designated as hazardous waste. If the nano-waste contains a listed hazardous waste material as a component in it then it will be designated as hazardous waste. Contact the CNS staff in charge of the area to determine if nano-waste is a hazardous waste. Nano particles in solvents will be treated as liquid hazardous waste. Gloves and wipes contaminated with any nano-waste material will be disposed of in containers labeled with the words “Contains nano-waste”. Do not dispose of any nano-waste into the regular trash. If not sure what to do with nano-waste ask CNS staff.

21 Chemical Exposure First Aid and Response

21.1 Immediately use eye wash / safety shower station to flush affected area with water for a minimum of 15 minutes.

21.2 Remove contaminated clothing while flushing with water.

21.3 Notify CNS staff and/or have someone call 5-5560 and obtain medical attention.

21.4 If suspect or confirmed Hydrofluoric Acid exposure:

21.4.1 Immediately rinse the affected skin with water

21.4.2 Remove all jewelry and clothing exposed to HF while rinsing in emergency shower for 5 minutes

21.4.3 Someone must call 911 and/or Operations Center at 617-49(5)-5560. MSDS for HF must be taken with person.

21.4.4 Apply Calgonate (calcium gluconate) to affected area using a clean chemical resistant glove.

21.4.5 Take Calgonate Gel with you and apply on the way to emergency room.

21.5 CNS and EHS ERT staff must do the following:

21.5.1 Ensure injured person has adequately flushed exposed area and removed contaminated clothing.

21.5.2 Assist individual in obtaining medical attention. Medical attention is necessary in the following situations:

21.5.2.1 Eye contact with any chemical.

21.5.2.2 Skin contact with hydrofluoric acid (HF, BOE).

21.5.2.3 Skin contact which results in redness, pain, or blisters.

21.5.3 Obtain Material Safety Data Sheet(s) of the chemical contacted.

22 How to Read an NFPA Hazard Communication Diamond

22.1 NFPA stands for National Fire Protection Association.

22.2 The NFPA “fire diamond” (Fig. 6) is a visual notification standard maintained by the US Fire Protection Association.

22.3 This diamond allows emergency and lab personnel to easily identify the hazards of a particular chemical or storage area.

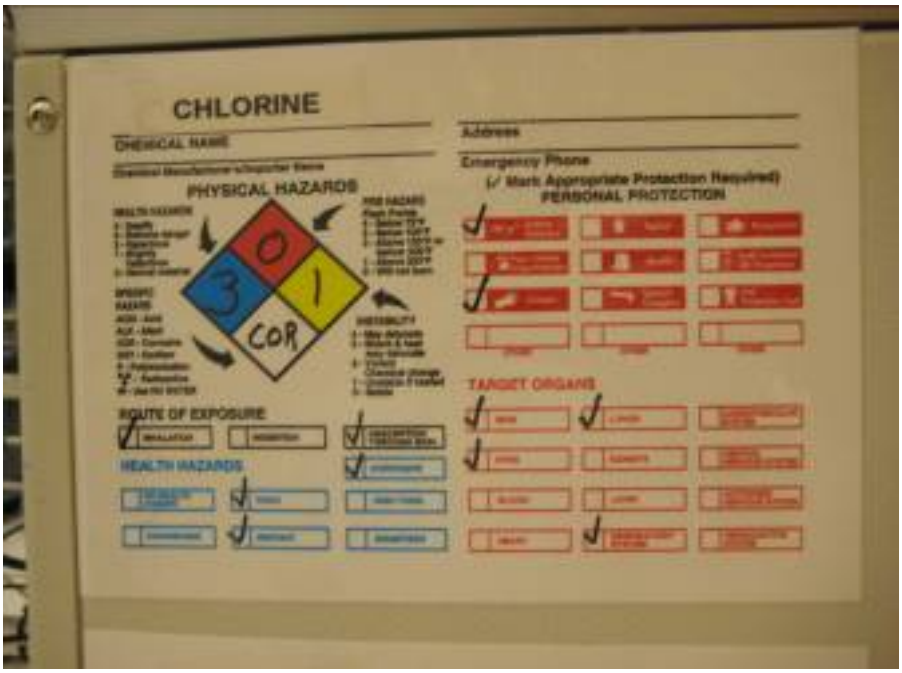


Figure 6: NFPA diamond.

22.4 Each quadrant of the diamond indicates a particular hazard. All users of CNS laboratories must be able to interpret these hazard indicators.

22.4.1 Blue Quadrant (Health)

22.4.1.1 4= Deadly

22.4.1.2 3= Extreme Danger

22.4.1.3 □2=Hazardous

22.4.1.4 □1= Slightly Hazardous

22.4.1.5 □0= Normal Material

22.4.2 Red Quadrant (Flammability -Flash Points)

22.4.2.1 □4=Below 73°F

22.4.2.2 □3=Below 100°F

22.4.2.3 □2=Below 100°F – not exceeding 200°F

22.4.2.4 □1=Above 200°F

22.4.2.5 □0= Will not Burn

22.4.3 Yellow Quadrant (Reactivity)

22.4.3.1 □4= May Detonate

22.4.3.2 □3= Shock and Heat May Detonate

22.4.3.3 □2= Violent Chemical Change

22.4.3.4 □1 = Unstable if Heated

22.4.3.5 □0=Stable

22.4.4 White Quadrant (Specific Hazard)

22.4.4.1 □OX = Oxidizer

22.4.4.2 □~~W~~ = Use no Water

22.4.4.3 ACID = Acid

22.4.4.4 □ALK = Alkali

22.4.4.5 □COR = Corrosive

22.4.4.6 □  □= Radioactive

23 Emergency Evacuation Procedures

23.1 **Fire Alarm**

23.1.1 If you hear the fire alarm, leave the cleanroom via the emergency exit doors. If in other labs, leave by nearest exit. Exit building through nearest stairwell.

23.1.2 Once outside, report to the rally point in front of Pierce Hall. Someone from EHS or CNS will be coming to ask if anyone is missing. This information will be communicated to emergency responders at the Fire Command Center (located at the front entrance to LISE and McKay).

23.1.2.1 If it is after 5pm Monday through Friday or on weekends, you personally can report any one missing to the Cambridge Fire Department at the Fire Command Center.

23.1.3 Do not re-enter LISE until Cambridge Fire Department gives the approval.

23.2 Toxic Gas Alarm

23.2.1 If blue toxic gas alarm sounds you must leave building and report to the front of Pierce Hall.

23.2.1.1 The blue light means that there is a gas leak in the ambient air near a cleanroom tool or in the M14 gas room.

23.2.2 If amber/yellow gas alarm sounds you must leave immediate area. Go to where there are no flashing/amber toxic gas strobes, for example the LISE lobby. If you want to inquire of the time it will take before you can re-enter the cleanroom you can visit the LISE Fire Command Center at front entrance.

23.3 Evacuation Routes

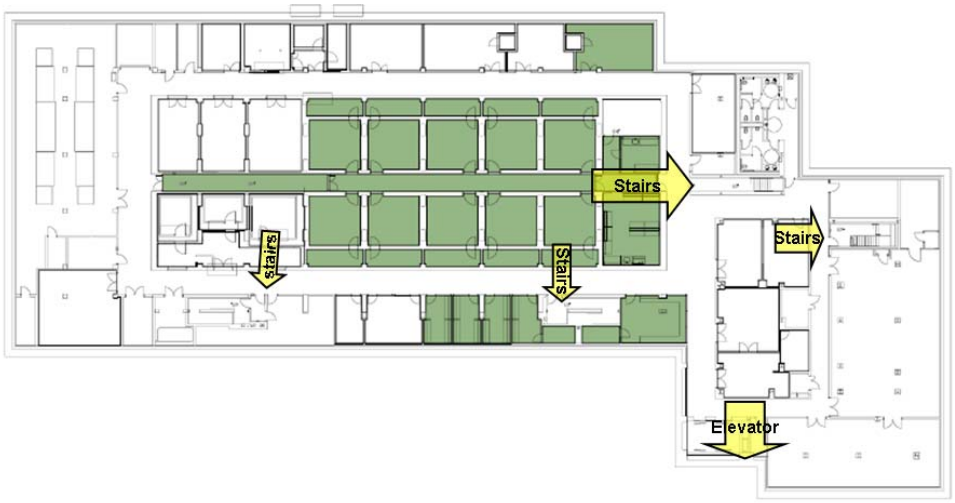


Figure 7: Evacuation routes, LISE basement.

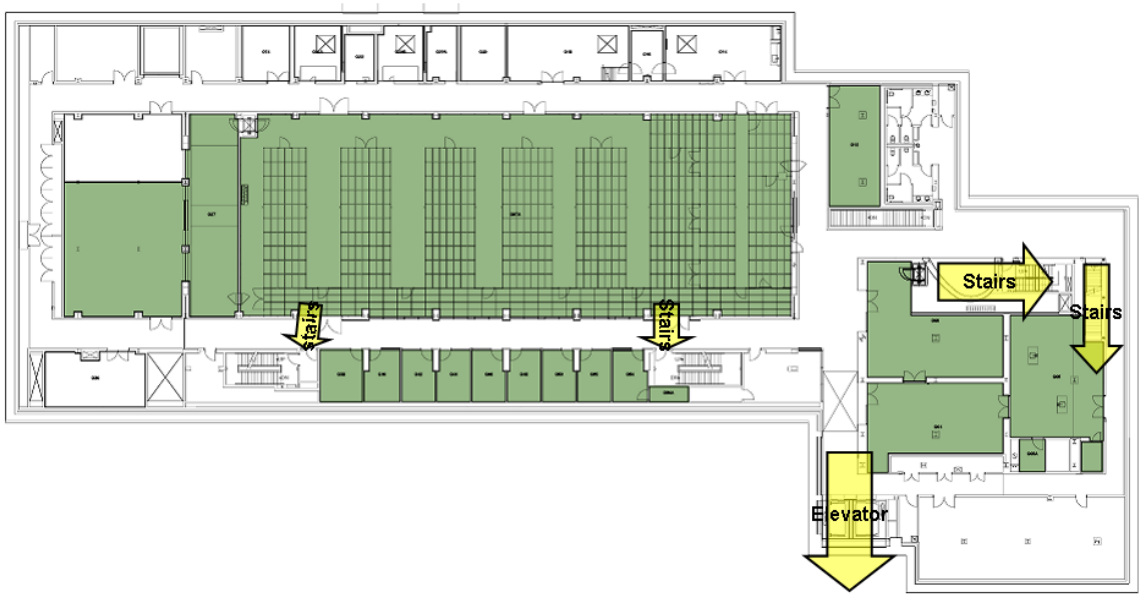


Figure 8: Evacuation Routes, LISE ground floor.

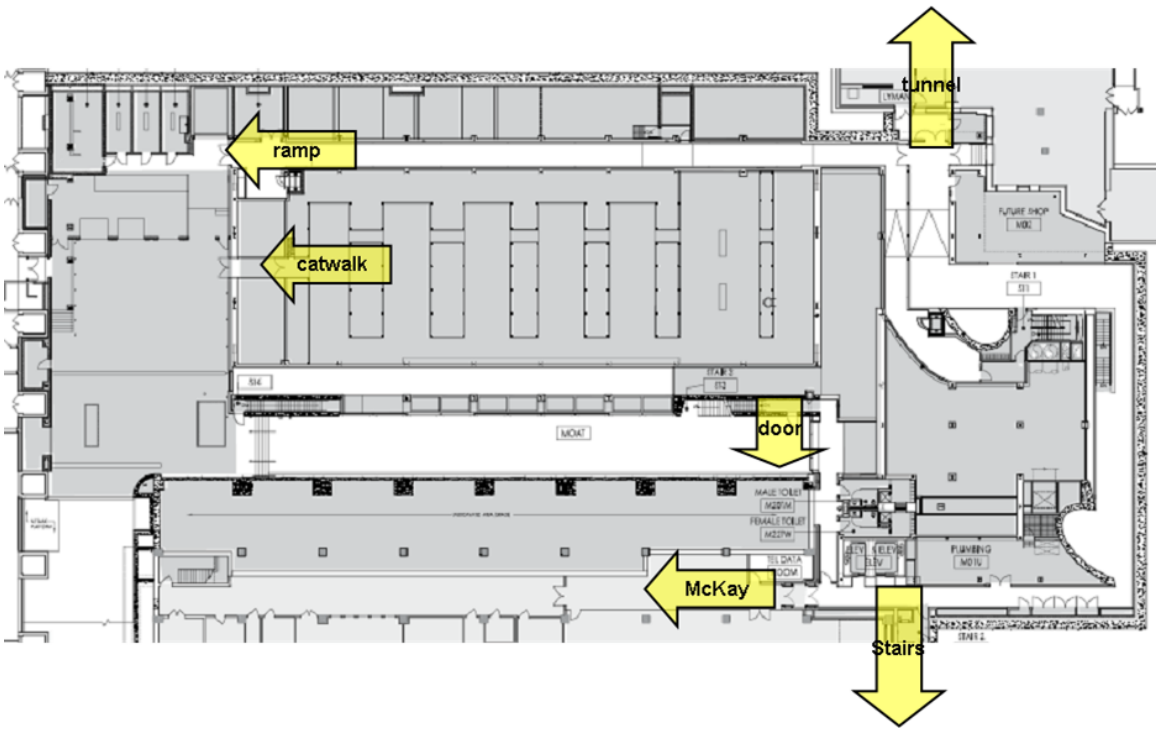


Figure 9: Evacuation routes, LISE mezzanine.

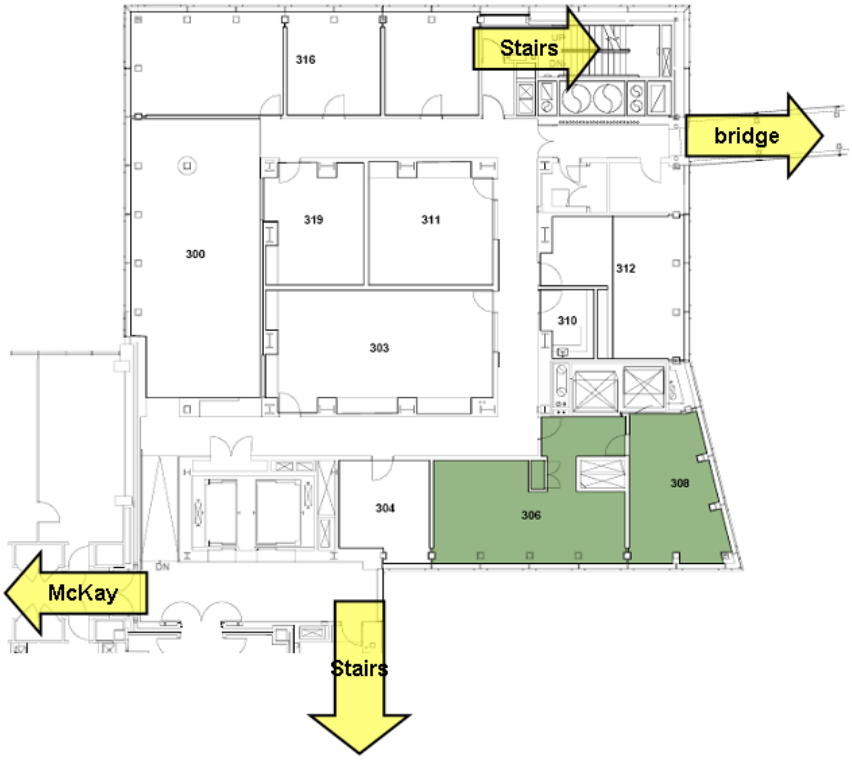


Figure 10: Evacuation Routes, LISE 3rd floor.

24 Non-Ionizing and Ionizing Radiation Awareness

24.1 **Ionizing Radiation**

24.1.1 Presently Uranyl Acetate is the only radioactive material allowed in the Center for Nanoscale Systems facility. Its use must be pre-approved by EHS. It may be encountered in G05 (BL2 area) and in B15A (imaging sample prep lab).

Users of Uranyl Acetate must take an online radiation training course at http://ehs.harvard.edu/training before using uranyl acetate. If you are a non-harvard user you must first attain an XID at https://xid.harvard.edu/

24.1.2 X-ray training is needed for personnel who use the Micro-Ct Scanner. Details as to what else is needed for this training can be found on the CNS web site under the Safety Section.

24.1.3 X-rays are present inside Scanning Electron and Transmission Electron Microscopes. Baseline X-ray surveys are taken of each SEM and TEM and the Micro_CT scanner. Additional surveys are performed every two-years. These measurements are performed to verify that X-rays are not leaking from these tools. If you would like to see a copy of the surveys you can contact the LISE EHS officer at 5-1290.

24.2 **Non-Ionizing Radiation**

24.2.1 **Lasers:** If you plan on using class IIIb and Class IV lasers you will need to take the laser safety course. You can see the schedule at http://ehs.harvard.edu/training You will also have to complete the requirements of FM007 “CNS Laser Safety Requirements”. For more safety and health related questions regarding lasers you can view the EHS Radiation Safety Manual at http://ehs.harvard.edu/programs/lasers

24.2.2 **Radio-Frequency Exposure:**

24.2.2.1 *Biological effects can result from exposure to RF energy. Biological effects that result from heating of tissue by RF energy are often referred to as "thermal" effects. It has been known for many years that exposure to very high levels of RF radiation can be harmful due to the ability of RF energy to heat biological tissue rapidly. This is the principle by which microwave ovens cook food. Exposure to very high RF intensities can result in heating of biological tissue and an increase in body temperature. Tissue damage in humans could occur during exposure to high RF levels because of the body's inability to cope with or dissipate the excessive heat that could be generated. Two areas of the body, the eyes and the testes, are particularly vulnerable to RF heating because of the relative lack of available blood flow to dissipate the excess heat load.*

24.2.2.2 *At relatively low levels of exposure to RF radiation,* i.e.*, levels lower than those that would produce significant heating; the evidence for production of harmful biological effects is ambiguous and unproven. Such effects, if they exist, have been referred to as "non-thermal" effects. A number of reports have appeared in the scientific literature describing the observation of a range of biological effects resulting from exposure to low-levels of RF energy. However, in most cases, further experimental research has been unable to reproduce these effects. Furthermore, since much of the research is not done on whole bodies (*in vivo*), there*

has been no determination that such effects constitute a human health hazard. –from http://www.fcc.gov/oet/rfsafety/rf-faqs.html#Q5

24.2.2.3 RF surveys of equipment that generate radiofrequencies (sputtering, reactive ion etches (RIE), and chemical vapor deposition (CVD) tools) are performed at commissioning and then every two years. If you need a copy of a survey, contact the LISE EHS Officer.

24.2.3 **Microwave Exposure:**

24.2.3.1 *Electromagnetic radiation in the 1 mm to 1 m wavelength range (300 MHz to 300 GHz) is referred to as microwave radiation, and is part of what is known as radiofrequency (RF) radiation. The latter covers the 0.5 MHz to 300 GHz range and is considered in the context of adverse biological effects. RF radiation is nonionizing radiation. This means that, in general, it does not have sufficient energy to kick an electron off an atom thus producing charged particle in a body and cause biological damage. The only proven harmful effect from exposure to microwave (or RF) radiation is thermal. RF radiation can enter deep into the body and heat human organs. Thus, the depth of penetration and the level absorption of radiation in the body are relevant.*

24.2.3.2 *Above 10 GHz (3 cm wavelength or less) heating occurs mainly in the outer skin surface. - From 3 GHz to 10 GHz (10 cm to 3 cm) the penetration is deeper and heating higher.*

24.2.3.3 *From 150 MHz to about 1 GHz (200 cm to 25 cm wavelength), penetration is even deeper and because of high absorption, deep body heating can occur.*

24.2.3.4 *Any part of the body that cannot dissipate heat efficiently or is heat sensitive may be damaged by microwave radiation of sufficient power. The lens of the eye and testes are respective examples. Are there non-thermal ADVERSE effects of microwave radiation in humans? We know that there ARE non-thermal effects: microwaves can cause hearing sensation, can affect behavior (in animal studies), etc.*

24.2.3.5 *Are these effects adverse and reversible? Research is still continuing in this area as well as in the area of RF radiation effects on immune and central nervous system. Much more work is needed and maybe you can get a degree in science and do some research in this area. Have said all this, it is my personal view that man-made effects (i.e., those that have not been a part of our natural history) have to be treated with caution, and lack of evidence for adverse effects is NOT the same thing as proof of safety*. From Dr. Ali Hounsary Advanced Photon Source Argonne National Laboratory
http://www.newton.dep.anl.gov/askasci/gen99/gen99445.htm

24.2.4 **Microwave Surveys** of equipment that generate microwaves (NEXX reactive ion etcher (RIE) and the NEXX chemical vapor deposition (CVD) tools) are performed at commissioning and then every two years. If a tool is moved it will also be re-surveyed. If you would like to have a copy of any microwave survey report, contact the LISE EHS Officer.

25 Biosafety

25.1 Any work involving human cell lines, human blood or serum or infectious agents must be performed in BL2 lab in room G05.

25.2 Before any biomaterials can be brought into any CNS laboratory, they must be requested through FM006 “CNS Material Request Form” and approved by EHS.

25.3 Before any biomaterials work is performed you must complete the requirements set forth in document FM009 Pre-Training Requirements for Biological Safety. It requires proof of attendance from the Harvard Biosafety Course.

See the following site for schedules. It occurs monthly. http://ehs.harvard.edu/training. If you are a non-harvard user you must first obtain an XID from this site https://xid.harvard.edu/

25.3.1

26 Other Hazards

26.1 Ultraviolet Light

26.1.1 Spectra of Ultraviolet Light

26.1.1.1 Ultraviolet light is a radiant energy which occupies the region between visible light and X-ray in the electromagnetic spectrum. The hazards of the emitted radiation depend upon the wavelength. The UV section of the spectrum is divided into three parts:

26.1.1.2 UV-A (315-400 nm): radiation equivalent to that received from the sun, and unless a person is especially sensitive, the most that can happen to his/her skin is that it will tan.

26.1.1.3 UV-B (280-315 nm): is the middle range of UV radiation, and it is more harmful.

26.1.1.4 UV-C (180-280 nm): overlaps X-rays, and must be dealt with under extreme precautions.

26.1.2 Symptoms of Overexposure

26.1.2.1 Ultraviolet burns of the eye (actinic keratinitis) are very painful, but not normally of lasting effect (UV-A and UV-B). Often an individual does not initially realize that they have been exposed. Hours after exposure, an exposed person may notice that their eyes become painful, feeling as if grains of sand are under the eyelid. Often the victim doesn't make the connection between working with UV-emitting light source and the pain being experienced.

26.1.2.2 Some studies connect UV exposure to skin cancer; severe burns are also possible.

26.1.3 UV Emergency Procedures

26.1.3.1 Any blemish that appears on the skin after exposure to UV radiation should be examined by a physician.

26.1.4 UV Safety Guidelines:

26.1.4.1 All workers using UV emitting sources must have eye protection (goggles or normal glasses). Most plastics and all glass are an efficient shield for UV.

26.1.4.2 If you are working with UV-C or high doses of UV-A or B, you should also protect your skin. Special creams are available for this.

26.1.4.3 If you are working with a UV emitting source, be certain that other people in your area are guarded from direct radiation. The use of plastic shields and prominently placed signs are helpful. Never look directly at the source. Also, be careful to avoid reflections from metal surfaces.

26.2 High Voltage

26.2.1 Lockout-tagout procedures must be followed when working on equipment that must be de-energized for service.

26.2.2 Leads exposed during service which are normally energized with 50 or more volts should be shrouded or taped for shock protection.

26.2.3 Equipment covers temporarily removed for service must be replaced as soon as possible.

26.3 Allergies to latex or other chemicals.

26.3.1 Some individuals may have an allergic reaction to latex gloves. The nitrile gloves provided in CNS labs should not produce this reaction.

26.3.2 If you observe an allergy, please seek medical attention and report to EHS.

26.4 Clothing on fire.

26.4.1 Stop, drop, and roll.

26.5 Power failure.

26.5.1 If a power failure occurs, please follow the protocol for an orderly dismissal from the laboratory. If possible leave chemicals and instruments in a safe state. All CNS labs have back-up emergency lighting for exit signs. Exit the laboratory and wait for power to return. Notify Operations Center if after hours.

26.6 Ventilation failure.

26.6.1 EXHAUST: If an exhaust failure occurs all chemical use must be suspended. Wet benches and hoods should alarm. Lower bench/hood shields. Notify Operations Center if after hours.

26.6.2 SUPPLY: If the cleanroom supply fails alone, the cleanroom will become negatively pressured with respect to the hallways. Leave laboratory – outward opening exit doors may require extra effort to open. Notify Operations Center if after hours.

27 Incident Reporting

27.1 FM022 “CNS Incident Report Form” should be used to report unsafe acts, ideas to improve environmental health and safety issues at CNS, equipment issues, or any recommendation. They are located in each CNS lab. Complete the form and submit following instructions. Any and all incidents will be reviewed by the LISE safety officer and the LISE Environmental Health and Safety Committee and the CNS staff.

27.2 Email to any CNS staff is also an acceptable way to communicate concerns about your safety at the CNS facility.

27.3 Accidents must be reported to the LISE EHS Officer.

28 Working Safely with Nanomaterials

28.1 Before working with nanomaterials it is required that you fill out FM008 “CNS Nanoparticle Safety Requirements Form”

28.2 What are Nanomaterials

28.2.1 Nanomaterials or nanoparticles are human engineered particles with at least one dimension in the range of one to one hundred nanometers. They can be composed of many different base materials (carbon, silicon, and various metals.

28.2.2 Naturally created particles of this size range are normally called ultra-fine particles. Examples are welding fumes, volcanic ash, motor vehicle exhaust, and combustion products.

28.2.3 Nanomaterials come in many different shapes and dimensions, such as:
0- dimensional: quantum dots
1- dimensional: nanowires, nanotubes
2- dimensional: nanoplates, nanoclays
3-dimensional: Buckyballs, Fullerenes, nanoropes, crystalline structures

28.3 Health Effects

28.3.1 Respiratory Hazards (see http://ehs.harvard.edu/programs/nano-science-technology

28.3.2 Dermal Hazards (see http://ehs.harvard.edu/programs/nano-science-technology

28.3.3 Ingestion Hazards (see http://ehs.harvard.edu/programs/nano-science-technology

28.3.4 Inhalation Exposure Control Methods (see http://ehs.harvard.edu/programs/nano-science-technology)

28.3.5 Dermal Exposure Control Measures (see http://ehs.harvard.edu/programs/nano-science-technology

28.3.6 Ingestion Control Measures (see http://ehs.harvard.edu/programs/nano-science-technology

28.3.7 Injection Control Measures (see http://ehs.harvard.edu/programs/nano-science-technology

28.4 Clean Up (http://ehs.harvard.edu/programs/nano-science-technology

28.5 Disposal (see

Revision History

Revision #	Date	Author (s)	Changes/Additions
0.6	5/21/09	J. Sweeney	Added sections.
0.7	5/22/09	E. Martin	Formatting cleanup.
0.8	5/26/09	EM	Restored from laptop.
0.9	6/2/09	JS	Added nanoparticle guidance.
1.0	7/29/09	SI/JS	Clarifications and formatting.
1.1	7/29/09	EM	Clarify scope of chemical compatibility chart.
1.2	8/12/09	EM	Updated evacuation route diagrams.
1.3	8/17/09	JS	Updated face shield use requirements in following sections: 5.4, 5.5, 5.17 and Section 10 PPE table
1.4	06/08/10	JS	Updated the following sections: 19 hazardous Waste, 12.6.10, 10.1, 10.3 and 10.4,
1.5	6/18/10	EM	Updated staff contact list
1.6	2/17/11	JS	Added sections: 5.3.4, 18.2.10; 18.2.1; 5.10.2; 5.10.4; 20.2.3; revised section 19.5, revised section 12.4.2
1.7	3/9/11	EM	Clerical corrections throughout.
1.8	3/15/11	JS	Added statement about the building fire alarm system sounding during a high level ambient leak in clean room or M14 room, added statement about amber light alarming when we lose exhaust to clean room and or any gas cabinet. Section 5.10.2 updated, Section 20.3.2 updated to include “hazardous waste bag”, in section 20.8.1 expanded on definition, I accepted all clerical changes made in rev 1.7
1.9	3/23/11	EM	Spell check; create pdf for internal review.
1.10	6/21/11	JS	Added information on Tetra methyl ammonium hydroxide (TMAH) in section 18 and section 10. Also changed name of section from ‘Specific Chemical Hazard Information’ to ‘Specific High Hazard Chemical Information’
1.11	12/2/2013	JS	Made corrections to website links throughout document

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