Lab-Specific Chemical Hygiene Plan (CHP)

General Information & Standard Operating Procedures (SOPs)

for the

Safinya Laboratories

(MRL rooms 1012, 1012B, 1016, 1024, 1032)

Chemical Hygiene Officer (CHO):

Alex Moretto (amoretto@ucsb.edu)

This page intentionally left blank

Table of Contents

Preface

All labs using chemicals are required by Cal-OSHA to have a written safety plan (Chemical Hygiene Plan, CHP) in place for chemical workers. It is the responsibility of the lab supervisor/PI to ensure that a complete Chemical Hygiene Plan is developed, implemented and shared with all affected workers. This CHP contains important, *lab-specific* safety information such as standard operating procedures (SOP) for common procedures done in the lab. The idea behind having these SOPs written out is to minimize exposure to hazardous chemicals for the people performing the procedures.

These pages should be filed under the "Chemical Hygiene Plan" tab of the lab's CHP binder. If you find pages or information missing from this binder, you do not understand parts of its content, or you need other help with chemical safety questions, contact

Kai Ewert	MRL room 2222		ewert@mrl.ucsb.edu
or			
Youli Li	MRL room 2202	x8104	youli@mrl.ucsb.edu
or			
UCSB EH&S		x4899	http://ehs.ucsb.edu

Introduction

This is section I (the lab-specific section) of the Chemical Hygiene Plan (CHP) for the Safinya Lab. It consists of three main parts. The first is general information which applies to everyone working in the lab. The next part contains a number of "Standard Operating Procedures" (SOPs) for processes in the lab which involve safety hazards. These are intended to give the user information about the potential hazards of the process and how to avoid these. The last part is an appendix containing a number of relevant documents, most prepared by UCSB EH&S.

The origin of the regulations requiring a CHP and SOPs assume an industrial production lab with fixed procedures. In academic research laboratories, however, procedures, materials, and hazards are constantly changing. Therefore, this document can never fully cover all safety issues in our lab. Instead, it strives to lay the foundation for safety in the laboratory by providing a framework upon which each lab researcher can build as well as a collection of safe best practices for commonly used procedures.

Due to the changing nature of work in an academic laboratory, it is the responsibility of each and every person working in this lab to do the inquiry, the literature research, and the thought required to understand and mitigate the hazards of their experimental work before they proceed with it. A good starting point is to get educated about the chemical hazards of the materials to be used (see the resources provided in this document). In addition, lab members should consult other people who have done similar work and feel free to contact Kai Ewert and Youli Li with questions or concerns. This CHP also includes an SOP for "Preparing For A New Project", which aims to give guidelines on this important subject.

Everyone working in the Safinya Laboratory needs to read this Chemical Hygiene Plan once and review it annually. Please document that you have fulfilled this requirement by signing a log sheet in the office of Kai Ewert, MRL room 2222.

Twelve Commandments for Lab Safety

(in place of a summary)

You will find more detailed information on all of these items on the following pages.

1. You **must not work** in the lab before completing your **safety trainings**.

2. Wear your **safety glasses** in the lab. Wear **closed-toe shoes**.
Wear **lab coat**, **gloves**, etc. **as required** (see reverse page).

3. **No food, drink, smoking** in the lab.

4. **Know** what you are doing and be aware of the **hazards** of your (and your neighbors!) work (chemicals, tools, processes): ask other lab members or consult relevant literature, e.g. the CHP, SDSs, etc.

5. **Do not pour waste down the drain**. Use the appropriate collection bottle. All **sharps** (glass, needles, blades) need to go into **designated containers**.

6. Always keep **fume hood sashes as low as possible**.

7. **Secure gas cylinders** to the wall with metal chains.

8. **Do not use damaged electrical cords.** Keep power strips off the floor.
Do not chain extension cords / power strips.

9. **Do not block lab aisles** with chairs, stools, or equipment.

10. **Store** only **compatible chemicals** close to each other.
Ask if you are not sure. Do not store heavy items overhead.

11. Do not touch doorknobs, phones, computers, etc. with gloved hands.

12. **Label** your samples with your name and the appropriate
chemical names.

UCSB Laboratory Worker Responsibilities

for Safety and Environmental Compliance

(from https://www.ehs.ucsb.edu/programs-services/injury-illness-prevention/employee-safety-environmental-responsibilities)

Every individual who works in a UCSB laboratory (employee, student, postdoctoral scholar, faculty member, or other person) has responsibilities for safety and environmental compliance.

1. Comply with applicable environmental, health and safety laws and regulations, University policy and accepted safe work practices as described in this Chemical Hygiene Plan.

2. Observe environmental, health and safety related signs, posters, warning alarms and written directions.

3. Learn about potential hazards associated with their work and work area; know where information on these hazards is kept for their review; and use this information when needed.

4. Participate in health and safety training applicable to their work situation.

5. Follow procedures and observe precautions for the use of special materials (such as carcinogens, acutely toxic chemicals, radioactive materials or biohazards), as detailed in the laboratory's use-authorizations, and Lab-specific Chemical Hygiene Plan, and the Safety Data Sheet (MSDS) for the material.

6. Always use personal protective equipment per UC policy and engineering controls (e.g., fume hoods) appropriate to the work and understand their proper operation.

7. Be familiar with the location and general content of the *UCSB Emergency Information Flipchart* posted in their area. Know the locations of their local safety shower/eyewash, fire extinguishers, first-aid kit and Emergency Assembly Point. Participate in emergency drills.

8. Curtail or stop their work if they reasonably believe continuation of the work poses an imminent danger to health or safety, and immediately notify their supervisor, or Environmental Health & Safety. Warn co-workers about defective equipment and other hazards.

9. Participate in required inspection and monitoring programs.

10. Never work under the influence of substances or circumstances that have adverse effects on cognition.

General Laboratory Information

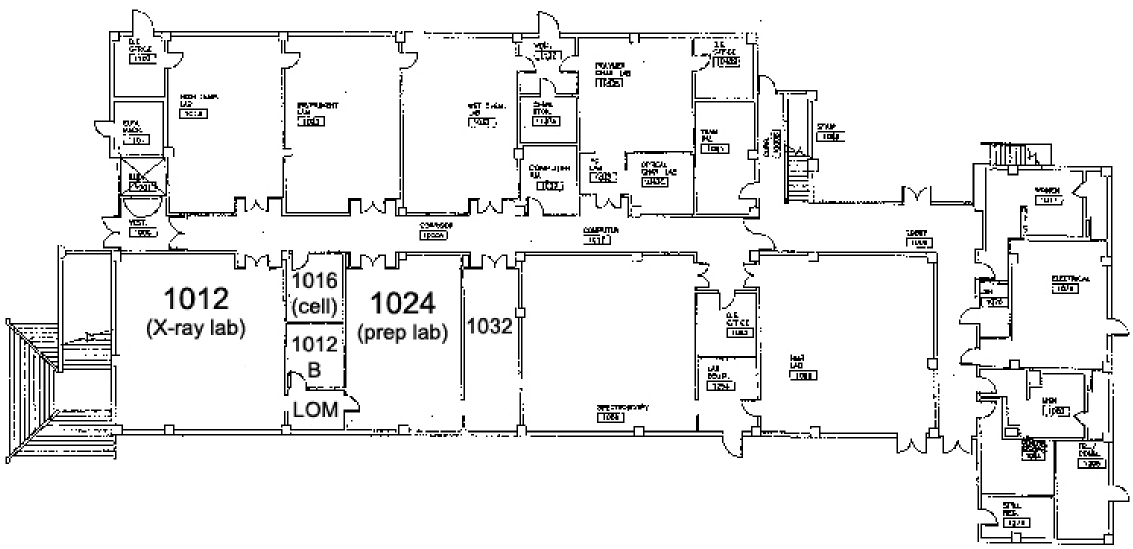
Laboratory Supervisor (PI)

Cyrus R. Safinya (MRL room 2204, x8635, safinya@mrl.ucsb.edu)

Laboratory Locations (Building /Rooms)

MRL (building 615), rooms 1012, 1012B, 1016, 1024, 1032 (floor plan below)

MRL FIRST FLOOR



Laboratory Safety Coordinators (Safety Czars)

Chemical Safety and MRL labs:

Kai Ewert (office: MRL room 2222, ewert@mrl.ucsb.edu)

X-ray Safety (and CNSI labs):

Youli Li (office: MRL room 2202, x8104, youli@mrl.ucsb.edu)

Department Information (MRL)

Department Safety Representative / Hazard Communication Coordinator

Amanda Strom (room 2066F; x7925, amanda@mrl.ucsb.edu)

For all safety matters that go beyond our lab or that can not be settled by talking to Kai or Youli, you may want to contact Amanda Strom, the Safety Representative for the MRL. He is also in charge of the overall maintenance of the MRL and several of the instruments housed here. Thus, he's a good person to know.

Location of the Department Safety Bulletin Board

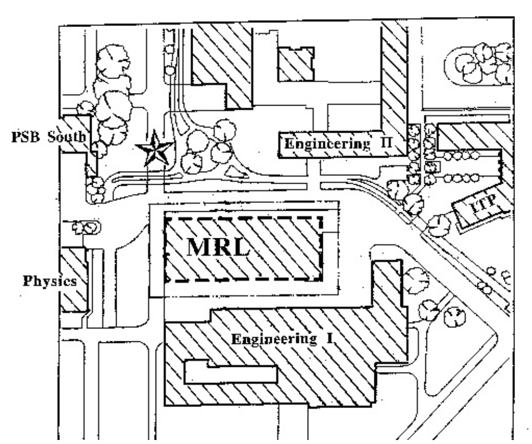
MRL room 2042 (2nd floor kitchen)

The MRL Safety Corner bulletin board is a place where safety and other important information concerning the whole MRL is posted. The next time you are using the fridge, getting water, or waiting for your food to warm up in the microwave, check it out.

Location of MRL Building Emergency Assembly Point (EAP)

The EAP is diagonally across the road from the main entrance of the MRL (in between Physics and Eng II) on the Isla Vista Side of the Eng II Building (marked by a star on the adjacent map)

Proceed to the EAP in the event of any evacuation or fire alarm, be it real, a drill, or a malfunction of the alarm system. Remain there until everyone is accounted for. Do not reenter the building until instructed to do so by authorized personnel.



Emergency Information

Emergency procedures

Campus EH&S has compiled helpful essential information on how to respond to a variety of emergencies and hazardous situations in a flip-chart type manual. A copy of this manual is posted next to each lab door. Contact Kai or Youli if you find one missing. More information on specific scenarios (fires, chemical spills, and earthquakes) is also provided below.

Remember that you need to dial 9-911 from campus phones for emergency calls (and 805 893 3446 from cell phones[1]). As soon as it is safe for you to do so, also notify Kai (cell: 805 252 4318) or Youli (x8104; 805 683 6754 after hours). If poisoning is suspected, contact Poison Control Center at 800 222 1222.

For emergency contact information regarding incidents in the lab, see the placards on the lab doors. If in doubt who to call, contact Kai, Youli (x8104) or Amanda Strom (x7925).

Evacuation procedures

If evacuation is advised (most emergencies with the notable exception of earthquakes), leave the lab as quickly as possible through the closest door that is not obstructed. Then proceed to the East (main, Isla Vista side) exit of the MRL and the Emergency Assembly Point (EAP) on the Isla Vista side of Eng. II (see map above). If the East exit is blocked, use the West exit (ocean/KITP side). Emergency exit plans for all three floors of the MRL are posted on the Safety Corner bulletin board (see above). The MRL EOP (on the web, see below) also has this information.

In the event of a fire, do not leave doors and windows open. If possible, operate the emergency power shutoffs before you leave the lab. If there is time to do so safely, take valuable personal property.

First-aid kit

A basic First Aid Kit is available next to the door in room 1012, on your left as you enter the lab – behind the station with the SDS/MSDS. The kit is maintained by Youli Li (x8104, youli@mrl.ucsb.edu).

Spill cleanup materials

A spill cleanup kit is located in the cabinet under the sink in room 1012 that is adjacent to the fume hood. EH&S should be contacted for any major or particularly hazardous cleanups (e.g. mercury spills from a thermometer) at x3194. This phone number is available 24 hours a day. After hours, emergency personnel can be paged through this

[1] simply dialing 911 from a cell phone will not contact UCSB dispatch, but rather the Ventura dispatch, which may result in delays

number. An SOP (Standard Operating Procedure) for handling chemical spills is provided in this CHP (page 115), and the EH&S flip-chart manuals (posted next to every lab and office door) also have information on what to do in the event of a chemical spill.

Laboratory monitors and alarms

The only lab monitors are low air flow monitors on the fume hoods. These are maintained by Campus Facility Management (x8300). They will sound an alarm (beeping) if airflow is at an unsafely low level. Do not override these alarms.

Fires

Below you will find information for the event of a fire in the lab or the MRL building.

Fire alarm and Evacuation Guidelines

The fire alarm in the MRL building consists of flashing strobe lights (these lights are mounted along the main hallways and also outside of the building) and an audible alarm. The audible alarm is a siren and a spoken message, notifying occupants of a fire and asking them to leave the building. If the fire alarm goes off, you must leave the building, no matter whether it is an actual alarm or a preannounced test of the system. **Do not use the elevators**, leave the building through the nearest available exit and find your way to the Emergency Assembly Point at the SW (Isla Vista) corner of Engineering II (see above).

Reporting a fire

For reporting a fire, a fire alarm pull station is located on the wall of the main hallway, near the main exit of the MRL (across from the elevator). This will be pointed out to you as part of your lab-specific safety training. Per SB County Fire and UCSB campus policy, **all fires must be reported to 9-911 immediately** – even if the fire is out. This is particularly true if there was use of an extinguisher (which always must be replaced, even if only used partially!), any injury, or property damage.

Fire Extinguishers

There are two types of fire extinguishers in the lab. The common standard are fire extinguishers that use powder. Each of the main rooms (1012, 1024, and 1032), have one of these, located next to the doors that lead to the hallway. These extinguishers can be used for any fire, including electrical fires. However, they make a gigantic mess and the fine powder that they dispense is not only hard to clean, it can also damage and destroy electrical equipment. Therefore, we also have an alternative, which is a CO_2 extinguisher. This is located next to the door in room 1012 (Safinya XRD lab). This is the type of extinguisher that you used in your lab safety training. Unless you are dealing with fire on electrical equipment, this is the preferred extinguisher to use.

If a fire extinguisher has been used, no matter for how brief, it must be replaced. Contact Kai Ewert or Amanda Strom to do this.

In the Event of an Injury

Follow the procedures outlined below, which can also be found on the blue emergency flip-charts located in every MRL office and lab (next to the door), under the heading "MEDICAL EMERGENCY".

Serious Injuries

If the situation is **immediately threatening to life or limb**, get emergency care, e.g. by calling 9-911 from any campus phone. This is preferred to taking an injured person directly to the Goleta Valley Cottage Hospital Emergency Room, where they may not be seen or treated for a long time if they don't arrive in an ambulance. There is no charge for having the paramedics come out and evaluate the victim. (If the victim needs to be transported to Student Health Services or a hospital emergency room there is a charge.) If poisoning is suspected, contact Poison Control Center at 800 222 1222. If an employee is hospitalized for more than 24 hours (other than for observation), or has an injury that results in partial or full loss of limb (amputation), or loss of life, contact EH&S at x3194 (24 hour phone line) immediately. The campus must report these injuries to OSHA within 8 hours of the event.

Other Injuries

It is important that all work-related injuries be reported immediately. Have your supervisor call the Work Injury Reporting Hotline at 877 682 7778 to report injuries and obtain an authorization for initial medical treatment.
For injuries **not** threatening to life or limb, **undergraduates and graduate students** may be treated at Student Health Services (SHS), phone number x3371. The partial map of the UCSB campus below shows Student Health Services at the top left corner:

Health & Safety References

NOTE: **Safety Data Sheets (SDS)**
(formerly known as Material Safety Data Sheets/MSDS):

Per OSHA regulations, all lab chemical users must know: a) what an SDS is; b) SDS relevance to their health and safety; and c) how to readily access them. These issues are all covered in the EH&S lab safety training. In brief, an SDS is a compilation of hazard/safety information for a given chemical or mixture, provided by the manufacturer. SDS often are the most readily accessed source of information about potential hazards of the chemicals you are working with. See below for sources of SDS and further information.

Written Safety Resources & References

Reference	Location
Lab Chemical Hygiene Plan aka the Black Binder	room 1012 (near door)
Yellow binder with Safety Data Sheets (This is where SDS for routinely used chemicals should be kept)	room 1012 (near door)
Merck Index	room 1012 (near door)
Biosafety in Microbiological and Biomedical Laboratories	room 1012 (near door)
Prudent Practices for Handling Hazardous Chemicals in Laboratories	room 1012 (near door)
Prudent Practices for Disposal of Chemicals from Laboratories	room 1012 (near door)
Dangerous Properties of Industrial Materials, 8th Ed.	office Amanda Strom (2066F)
Health And Safety Binder (aka The Green Binder)	office Amanda Strom (2066F) and online (see below)

Electronic Safety Resources & References

Reference and Location

EH&S page with electronic SDS resources

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/safety-data-sheets

MRL Safety webpage

http://www.mrl.ucsb.edu/mrl-safety-information

UCSB Environmental Health and Safety (EH&S) main website

http://ehs.ucsb.edu

Note: UCSB EH&S has posted vast amounts of useful safety information on their web page, but it is not always easy to locate. Some subjects covered (use the Search function on the site to find it) are listed below (see also the following references)

- Introduction to Campus Procedures and Resources
- Personal Protective Equipment in UCSB Storerooms
- Eyewear Policy and Selection
- Selecting the Proper Gloves
- Chemical Spill Cleanup Procedures
- Hazardous Waste Disposal Procedures
- Fire Fighting and Extinguishers
- EH&S Lab Safety Class Descriptions
- Laboratory Self-Inspection Checklist (see also Appendix E)

Health And Safety Binder (aka IIPP or The Green Binder)

https://www.ehs.ucsb.edu/programs-services/injury-illness-prevention/ucsb-health-safety-binder

Lab Safety Info at UCSB EH&S website

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene

Emergency Assistance Info

http://www.emergency.ucsb.edu/contacts

EH&S list of trainings on a variety of lab safety topics

https://www.ehs.ucsb.edu/training

Lab Safety Fact Sheets (one to three page summaries of important safety issues by UCSB EH&S and links to similar resources on other campuses)

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/fact-sheets

Note: **These are a good first stop for safety information** and are available on the following subjects. Appendix A contains the fact sheets marked with an asterisk (*); appendix G contains the fact sheets marked with a hashtag (#).

Chemicals

- Arsenic
- Azides, Handling Organic*
- Benzene*
- Cadmium
- Carcinogens
- Dichloromethane*
- Ethidium Bromide
- Formaldehyde*
- Hydrogen Fluoride
- Perchloric Acid
- Picric Acid
- Pyrophoric Organolithium Reagents#
- Water Reactive and Pyrophoric Materials#

Chemical Safety

- Chemical Storage*
- Chlorinated Solvents*
- Corrosives
- Cryogens*
- Housekeeping Guide for labs*
- Nanomaterials*
- Peroxides*
- Power Failures Guide*
- Quenching Solvent Drying-Still Bottoms
- Guidelines for Receiving Hazardous Materials Shipments in Non-Lab Areas
- Seismic Hazard Reduction*
- Sigma-Aldrich Technical Bulletins: Pyrophoric Reagents#
- TA Guide
- Time Sensitive Chemicals*

Lab Equipment

- Centrifuge*
- Electrophoresis*
- Environmental Rooms
- Compressed Gas Cylinders*
- Refrigerator & Freezers in Lab*

Hazardous Waste

- Chemical Waste*

Hazardous Waste Refresher (online course)

http://www.ehs.ucsb.edu/training/ucsb-hazardous-waste-generator-training

Sign up for this training (course code EH23) at the UC Learning Center:

https://www.learningcenter.ucsb.edu/

Accident Descriptions on the EH&S website (every accident has a lesson to teach)

http://www.ehs.ucsb.edu/labsafety/laboratory-accidents

An on-line source for Laboratory Chemical Safety Summaries (LCSSs) of some common chemicals is the book “Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, Updated Version” (National Academies Press, 2011) available on the web as an “open book” at

http://www.nap.edu/catalog.php?record_id=12654

Collection of LCSSs on PubMed:

https://pubchem.ncbi.nlm.nih.gov/lcss/

Safety in Academic Chemistry Laboratories, American Chemical Society, 7th ed., 2003. This work comes in two volumes, one for students and one for faculty/administrators. Look for it online or request a PDF from Kai Ewert.

Important Phone Numbers and Contact List

Emergency phone numbers

These are good to have programmed into your phone. In an emergency, you should always call 911, if possible from a landline. Give them the building, floor and room number and any other location-identifying information you can such as west side of the building near the elevator. **The MRL is building number 615.**

also more at https://www.ucsb.edu/contact/emergency

Campus non-emergency dispatch: (unlock doors after-hours and dispatch facilities for after-hours maintenance)	(805) 893 3446
Night-time escorts:	(805) 893 2000
EH&S 24/7 technical assistance:	(805) 893 3194

In an Emergency: Call

911	**from payphones, residence hall phones**
9 911	**from campus phones**
805 893 3446	**from cell phones (when on campus)** (simply calling 911 from a cell phone will not contact UCSB dispatch, but rather the Ventura dispatch, possibly causing delays)

Call 800 222 1222 (Poison Control Center) if poisoning is suspected

- Also consult the flip-chart manual posted next to every lab and office door

Other important phone numbers

Facilities management		(805) 893 8300
For fire extinguisher recharge		(805) 893 3305
Student Health Services		(805) 893 3371
EH&S 24-hour hotline		(805) 893 3194
Campus emergency information	(55c / call or min)	(900) 200 8272
Highway information (Caltrans)		(800) 427 7623
UCSB Emergency Operations Center campus status		(805) 893 8690

The following two pages reproduce an older “EH&S Guide to services phone list” (from a cell phone, dial (805) 893 before the extension);

up to date information is available at

http://www.ehs.ucsb.edu/programs-services

UCSB Environmental Health & Safety Guide to Services

The office of Environmental Health & Safety (EH&S) is committed to promoting a safe and healthful environment for research, instruction and the campus community. Through education, auditing and monitoring, technical consultation, and the provision of direct services. EH&S assists the campus in meeting its obligations for compliance with State and Federal health, safety and environmental regulations.

Asbestos/Lead (D&CS) x7984

Monitors building projects to ensure against releases of asbestos fibers or lead. Provides annual notification to employees of known asbestos in campus buildings. Teaches protective measures to employees who have potential for occupational exposure.

Biological Safety x8894

Facilitates compliance of biohazardous research to regulations and NIH guidelines. Reviews protocols involving potentially infectious organisms, toxins and certain recombinant DNA strategies to ensure the safety of people and the environment from any adverse effects.

Diving Safety x4559

Oversees all SCUBA programs and provides the training, dive planning and logistical support required for researchers to conduct their work underwater.

Emergency Management x3154

Implements strategies and procedures to prepare the University for potential emergencies. Educates the campus community on emergency preparedness, response and recovery topics.

Environmental Compliance x8533

The Environmental Health Program assists the campus community with its environmental (air, water & soil) health/compliance obligations. Assistance is provided in the form of information, guidance and/or technical support.

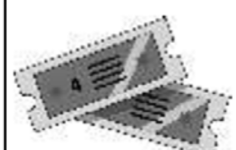
Environmental Health x8533

Oversees the community health and sanitation programs, including food operations, water quality, pest management, and pool sanitation.

Ergonomics x3283

The science of designing user interaction with equipment and workplaces to fit the user. It relates to the reduction of injuries in all types of jobs. Services include job task evaluation, body mechanics/back care training, evaluations/recommendation of product/tools, and workplace/workflow design to maximize efficiency and comfort for employees.

Event Management x7751



Monitors events and assists groups in meeting fire and life safety requirements. Provides emergency awareness training and develops emergency response plans related to fire and emergency evacuation.

Fire Protection x4407

Assists employees in identifying and eliminating workplace fire hazards. Approves building and renovation plans to ensure compliance with fire and life safety codes. Provides instruction on fire alarm systems and fire protection equipment. Provides training in fire and life safety and offers classes in fire extinguisher use.

General Safety/ Injury Prevention 2661x2306

Manages programs on accident investigation, shop safety, fall protection, lock-out/tag-out, driver safety, vehicle and equipment safety, CPR/First Aid, injury prevention efforts as well as general campus safety hazards. Provides consultation, training and certification.

Technical Assistance Phone: 893-3194 | General Information: 893-7534 | Fax: 893-8659

dfs/ALL_EHS/Publications/Guide to Services/EHS GTS Flyer

Environmental Health & Safety Guide to Services

Hazardous Chemical Management x8243

Maintains lab door placard program to provide information to emergency responders. Monitors campus use of large quantity chemcials, toxic gases and other hazardous materials for compliance with applicable local and federal regulations.

Hazardous Waste Disposal x3293

Manages disposal of all chemical waste generated on campus. Program includes waste pickups, pollution prevention, regulatory compliance, and maintaining emergency response capabilities.

Industrial Hygiene/Occ Health x8787

Provides information, consultation and training on industrial hygiene/occupational health subjects such as respiratory protection, hearing conservation, heat illness, confined space and hazard communication. Conducts IAQ surveys, exposure assessments and recommends control measures.

Injury & Illness Prevention x4899

Coordinates development of departmental Injury and Illness Prevention Programs with Department Safety Representatives (DSRs).

Lab Safety x4899

Provides training, information and inspections to foster safe and legal lab practices to protect workers against chemical and physical hazards. Reviews all new lab construction and renovation plans. Assists labs in developing their OSHA Chemical Hygiene Plans. Investigates lab accidents and coordinates hazardous materials emergency response activities.

Laser Safety x3588

Provides training, safety information and laser safety audits to assist compliance with applicable policies and regulations.

Radiation Safety x3588

Provides training, laboratory inspections, radiation exposure monitoring for both radioactive material and X-ray producing machine users. Manages the campus radioactive waste disposal program, including waste pickup, storage and disposal.

Risk Management x2860

Protects the campus from the risk of unanticipated loss, manages UC's insurance programs, manages the campus response to lawsuits and claims, analyzes risks involved in campus activities and use of facilities, resolves contract insurance and indemnification issues.

Stormwater Management x7014

The purpose of stormwater management is to protect and restore the physical, chemical, and biological integrity of our nation's waterways by controlling and limiting discharges of pollutants to these waterways.

Training x8997

Assists supervisors in meeting legal requirements to train each employee in health and safety practices and occupational hazards by providing classes, videos, publications, and manuals.

Workers' Compensation x8050

Workers' Compensation is a state-mandated insurance plan designed to be a "no-fault" system. Provides benefits and assistance to all employees who are injured or develop a job-related illness as a result of their employment.

Related Phone Numbers

Pest Control on Campus, for example:	
Rodents, Raccoons, Insects, Birds (live):	
Facilities Management	893-2661
Dogs (running loose):	
County Animal Control	681-5285
Marine Animals:	
Live: Marine Mammal Center	687-3255
Dead: Fish & Game	568-1226
Injured Animals:	
Wildlife Care Network	966-9005
Dead Animals in buildings or on roads:	
County Animal Control	681-5285
Environmental Health Issues at Home	
County Public Health Department	681-4900
Food Permits for Student Groups	
Office of Student Life	893-8912
Hot Work Permits	
Physical Facilities - Indoors	451-8996
EH&S - Outdoors	893-3785
Household Hazardous Waste Collection Center	
County of Santa Barbara	882-3602
Recycling Program	
Associated Students	893-7765

Contact information for Lab members and Amanda Strom

See also the Safinya Lab website at http://www.mrl.ucsb.edu/~safinyaweb/

Lab phone numbers: x4859 (MRL labs) and x5726 (CNSI X-ray lab)

(From a cell phone, dial (805) 893 before the extension)

	Office Phone	Cell Phone	Email
Kai Ewert		(805) 252 4318	kaiewert@ucsb.edu
William Fisher		(858) 945 7006	williamsfisher@ucsb.edu
Bretton Fletcher		(858) 539 3409	brettonfletcher@gmail.com
Aria Ghasemizadeh		(747) 304 0440	ariaghasemizadeh@umail.ucsb.edu
Youli Li	x8104	(805) 252 6315	youli@ucsb.edu
Phillip Kohl		(818) 434 1322	phillipkohl@gmail.com
Cyrus Safinya	x8635	(805) 708 2591	cyrussafinya@ucsb.edu
Amanda Strom	x7925		strom@ucsb.edu
Christine Tchounwou		(769) 237 1024	ctchounwou@ucsb.edu
Miguel Zepeda-Rosales	x7943	(831) 840 6820	miguelz@mrl.ucsb.edu

`

Safinya Lab Chores

A few times a year, we assign lab chores to the active group members. These include being responsible for certain pieces of equipment (e.g., inverted microscope), certain areas of the lab (e.g., the "LOM"), or certain tasks (e.g., ordering supplies). If you are tasked with caring for a piece of equipment chores, make sure to read the manual for this piece of equipment and learn any maintenance procedures from the person you might be taking over from (e.g. alignment and cleaning for microscopes). Getting trained by the person you are taking over from does not substitute for reading the manual though.

The current chores list, which you should consult if there is an issue with a piece of equipment, is posted in the lab.

Earthquake Safety

There will be a big earthquake in Santa Barbara. The only question is when.

All storage, especially of heavy objects, chemicals and glass, must ensure that the stored materials will not fall and become a hazard, obstruct escape routes or injure someone in a large earthquake. All gas cylinders need to be secured with a welded link metal chain. Furniture taller than 42 inches must be secured to the walls. Alert Amanda Strom, Youli Li or Kai Ewert if you notice unsecured furniture.

During an earthquake, you should try to stand in a doorframe or crouch under a desk until all shaking has stopped and only then evacuate the building.

Lab Safety

Introduction

Welcome to the Safinya Lab!

This document intends to provide you with some essential information that will help you work more efficiently and safely in our lab. In addition, it aims to give you a central repository of useful information, such as contact info for lab members etc. If you have suggestions on what else to include, please let Kai Ewert know.

If there is any safety-pertaining information in this document that you do not understand completely, seek clarification from Kai Ewert or Youli Li (contact information at the beginning of this document).

It almost goes without saying that doing your work in the lab in a way that is professional, safe, environmentally responsible and respectful of the needs of others is the basis for everyone working successfully while at the same time enjoying it. We have students and postdocs from a variety of backgrounds in the lab. Many of them will work in areas new to them. This poses a particular challenge for working safely, be it with biohazards or hazardous chemicals. Thus it is important for more experienced lab members to share their knowledge of how to work safely and efficiently. Everyone needs to work in the safest possible manner, not only to ensure their own and their coworkers' safety, but also to comply with the many laws and regulations about safe work practices that apply to the university environment. In the interest of everyone's safety, it is further important for all lab workers to be aware not only of the hazards and safety requirements of their own work, but also of that of their coworkers.

It is the responsibility of each and every person working in this lab to do the inquiry, the literature research, and the thought required to understand the hazards of their experimental work before they begin it.

To be allowed to work in the lab, you must complete the required safety training (see below) and complete and file the MRL Participant Form with Sylvia Vogel. This form directs participants to the required safety training beyond laboratory issues including fire, earthquake, ergonomics and more.

Safety Training Requirements

Every person working in the lab is required to take the in-person EH&S Laboratory Safety class before starting any work in the laboratory. No lab keys will be issued to you unless you have taken this class and this has been documented.

An in-person class is held at the start of each quarter. In the fall the class is provided for incoming graduate students at several science departments and at the College of Engineering. In summer there is a special class just for interns.

The in-person quarterly training schedule is announced by e-mail one to two weeks before the class and is posted online. Make sure you are on the MRL email lists so you get this and other important announcements.

In addition, there is an online lab safety course available. Lab users may get **temporary** lab access, until the next in-person class, by completing the **online training course and test** (see below). They must attend the next available in-person class to retain lab access privileges. Undergraduate lab researchers who work in the lab one quarter or less are only required to take the online lab safety class but are encouraged to take the in-person class.

The online training is accessible (course code LS60) at the UC Learning Center:

https://www.learningcenter.ucsb.edu/

In addition to the EH&S class(es), every person working in the lab also has to go through a brief **lab-specific training**, for which you should see Kai Ewert once you've completed your EH&S class.

Furthermore, all lab users are required to **read the safety-related documents listed below** and document that they have read them within 2 weeks of starting work in the lab:

- The Chemical Hygiene Plan (CHP) for the Safinya Lab. This is meant to be the main safety resource for the Safinya Lab.

- The MRL Emergency Operations Plan (also Emergency Action Plan & Fire Prevention Plan) (see Appendix C) available at

  http://www.mrl.ucsb.edu/mrl-emergency-operations-plan

- The MRL Combined Injury & Illness Prevention Plan and Hazard Communication Plan available at

  http://www.mrl.ucsb.edu/mrl-injury-illness-prevention-plan

All safety training needs to be documented. Please see Kai Ewert with any records of safety trainings that you have completed.

As much as it may seem, all of the above is just the foundation of the laboratory safety training. Everyone working in the lab must do the appropriate inquiry, literature research, and thought to ensure that the specific lab work they do is performed safely. The actual preparation will vary depending on what the project will be, but will certainly include studying the chemical hazards of the materials to be used and speaking with people who have done similar work. More work may be necessary, such as reviewing any physical or electrical hazards and considering if specialized personal protective equipment is required. Consult the information below as well as the SOP on “Preparing for a New Project” for more guidance on how to go about this and what resources are available.

Fundamental Lab Safety Rules and Precautions

In addition to the guidelines provided below, it is recommended that you go over the Laboratory Safety Self-Checklist in Appendix E. This document is also available on the web at
https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/laboratory-safety-review-program

direct link to the checklist:
https://www.ehs.ucsb.edu/sites/default/files/docs/ls/Lab_Self_InspectionChecklist_web_July2022.pdf

General

No storage or consumption of food and drink is permitted in the lab. An exception is the area connecting rooms 1012 and 1024 (the “LOM area”), which is not a designated lab area. (No lab work must be performed in the LOM area, and gloves must not be worn when handling anything there.) While food is permitted in LOM, it must be in **a closed**

container when transitioning through the lab space. Use common sense when transporting food to the LOM, e. g., don't use the door/lab where someone is working with hazardous material.

No food must be stored in the freezers or refrigerators in the lab. The lab microwave must not be used for food.

Smoking is prohibited anywhere in the lab (and on the UCSB campus), including the LOM area.

Do not block lab aisles with chairs, stools, or equipment. Maintain a minimum clearance of 2 ft in the aisels at all times.

Lab Equipment

Some of the equipment in the lab poses dangers when not used properly. This particularly includes the X-ray diffractometers (dangers due to high voltage and ionizing radiation) and the confocal microscope (dangers due to laser radiation). You must receive proper instruction on how to work with these instruments prior to using them.
Instruction manuals for most of the equipment in the lab are kept in the file cabinet next to the single hood (the "liposome prep" hood) in 1024. The manual for the biosafety cabinet (BSC) in the cell room is on top of the BSC, while microscopy-related manuals are in microscopy lab. Kai also has some manuals in his office.

Electrical Safety

Below are a few important items pertaining to electrical safety in the lab.

- Circuit breakers for the labs are located in the main hallway, outside of the labs.
- Do not use damaged electrical cords. Have these replaced or repaired properly; do not attempt to do the repair yourself.
- Do not use extension cords in place of permanent wiring, but only on a temporary, immediate, basis. Extension cords must be 14-gauge (heavy duty) at a minimum and must not be run through walls, ceiling or doors.
- Do not chain extension cords or connect them to power strips.
- Power strips must have circuit breakers.
- Keep power strips off the floor: the labs have no floor drains and flooding is a real possibility that may happen for a variety of reasons (e.g. extreme rainfalls or equipment malfunction, both of which have flooded the lab in the past).

Gas cylinder handling

All gas cylinders need to be secured with a welded-link metal chain so they do not fall over in an earthquake. When moving a gas cylinder, place the safety cap over the valve before undoing the chain securing the cylinder. Use the special dolly for gas cylinders that is kept in the MRL gas cage (across the little parking lot on the ocean side of the building). Date the cylinder when you place it in the lab.

Centrifuge Safety

The energy stored in the moving rotor of a centrifuge can be substantial and pose a hazard to equipment and personnel; the larger and faster the centrifuge, the greater the energy. It is imperative that the rotor is balanced, which is generally achieved by placing samples of identical weight in directly opposing positions. This is essential for the safety of the samples, the equipment, and the operator. A short video on centrifuge safety can be found at https://www.youtube.com/watch?v=q_0phA034n0

For additional information, see the EH&S lab safety fact sheet on centrifuges in Appendix A.

Pipetting Safety/Ergonomics

Always use a pipetting aid (e.g. rubber balloon style) and not your mouth for pipetting. If you use Eppendorf-style pipets a lot, make sure to familiarize yourself with proper pipetting technique to prevent repetitive use injuries. See, e.g. the short video at

https://www.youtube.com/watch?v=bqAsXMSs27s

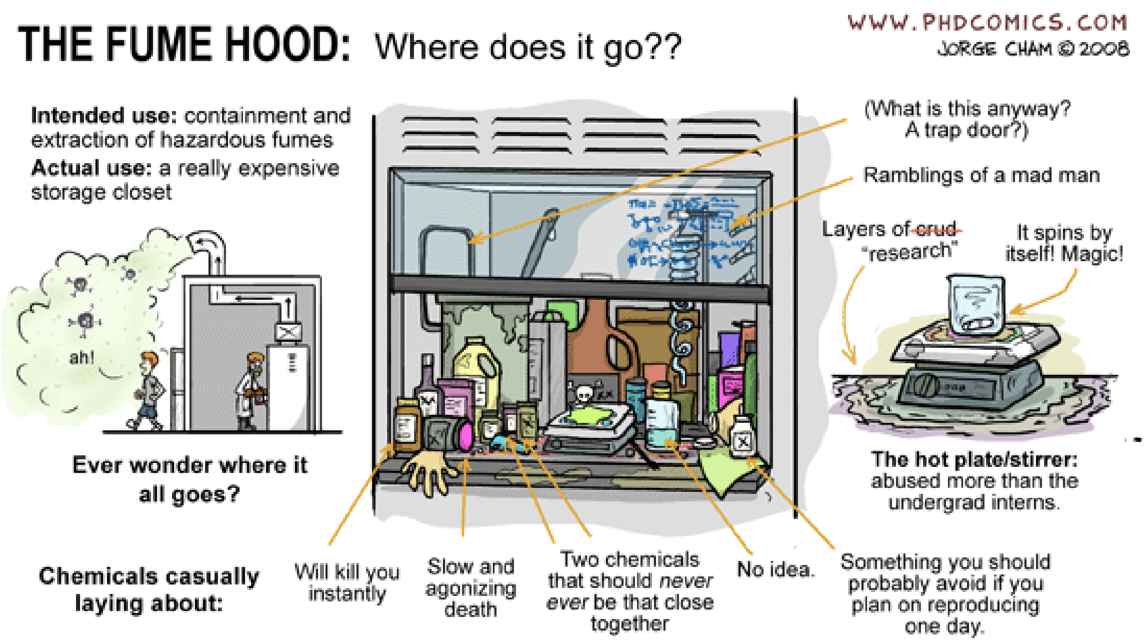
It is also important to learn proper pipetting technique to make sure you don't compromise validity of your research. One point particular to our lab is using Eppendorf-style pipets for dispensing organic solvents. Due to the high vapor pressure of these solvents (e.g., chloroform, methanol), it is essential that you pipet the solvent up and down a few times before measuring it out. This prevents the vapor pressure of the solvent from pushing out some of the liquid before you transfer it. It is also important to minimize the time the pipet tips are exposed to organic solvents because the solvent will leach compounds from the plastic. A quick test to check your pipetting skills and the calibration of the pipets is to dispense water or solvent to a container on a scale, recording the weight after each addition and using the known density of the dispensed liquid to calculate how well you did.

Chemical Safety

Transporting Chemicals

Always transport chemicals in a manner that minimizes the chance of accidental exposure. Keep bottles closed and minimize the chance that a container might drop and break. For transport of larger (≥ 1 L) glass bottles with chemicals, use designated carriers or plastic buckets.

A Humorous View of Chemical Safety OR What to Look Out For



Fume Hood Usage

Always handle volatile and hazardous chemicals in a fume hood. All fume hoods in the lab have simple airflow indicators. Check these periodically to ensure that the fume hood is working properly. Keep the air slots in the back of the hood free from obstructions. Never tamper with the electronic air flow alarms of the fume hoods in an attempt to permanently override them.

A single fume hood can use the same amount of energy as three to four homes (http://fumehoodcalculator.lbl.gov/). For the hoods in the Safinya labs, air flow and thus energy consumption depends on the position of the sash. Therefore, as well as for safety reasons (having many sashes open in the building will result in lower airflow because of the limited capacity of the fans serving the fume hoods) **always keep fume hood sashes as low as possible.** Keep only items that are in use inside the fume hoods. Several of the hoods have ventilated storage cabinets underneath the hood surface. These, rather than the fume hoods, should be used for storage of hazardous materials.

Identifying Chemical Hazards

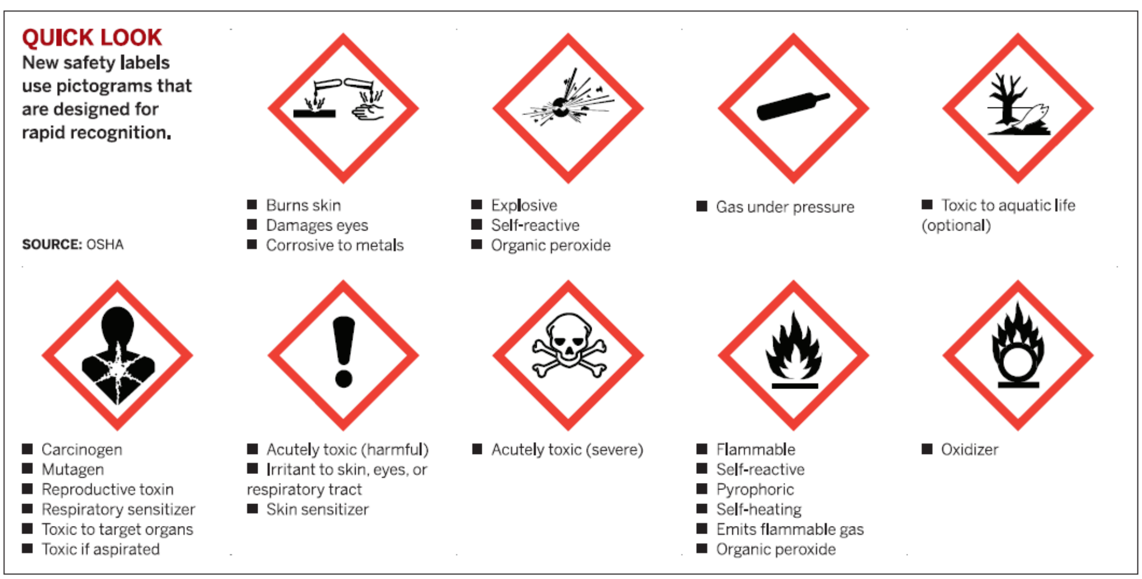
Every lab worker has the responsibility to learn about and understand the hazards of the chemicals they use **before** starting to use those chemicals. Do not assume that a material is harmless just because you haven't heard otherwise. Many chemicals are harmful, and some chemicals are mostly harmless by themselves but very dangerous in combination with certain other chemicals.

Besides talking to other people in the lab that use these materials (but don't assume that they have done their homework, even if they are senior to you!!), these are some resources:

- Safety Data Sheets (SDS; formerly known as Material Safety Data Sheets/MSDS). Widely available online (see the "Resources" part of this section of the CHP, or the corresponding part of section II), they are especially useful for mixtures, but also for reagents. SDS were intended to be a one-stop source of chemical hazard information, but they frequently are not very specific, not as succinct as one would like, and make everything sound extremely hazardous because they err on the side of caution e.g. for personal protective measures.
- Laboratory Chemical Safety Summaries (LCSS) are available for far fewer compounds, but more succinct and useful. Sources for LCSS are listed in the "Resources" part of this section of the CHP.
- The Merck Index is a compendium that has relevant information for many common chemicals. A copy of the Merck Index is kept in room 1012 next to the door.
- The "Resources" part of this section of the CHP

Chemical safety labels

In 2012, OSHA released an update to the regulation that determines how chemical safety information is relayed to workers. The main changes are standards for safety data sheets (SDS; formerly Material Safety Data Sheets, MSDS) and new chemical labeling which includes hazard-alerting pictograms. These are the pictograms and their meanings:



The update to the regulations also introduced new hazard classes. These may be confusing, because different types of hazards will be ranked by severity, starting with "1" as the most hazardous. But not all classes have the same number of ranking levels, and the severities can not be compared between classes—one class's category "1" is not necessarily more dangerous than another's category "2". The order of rankings is also the reverse of those used on the U.S. National Fire Protection Association diamonds, which use “0” for least and “4” for most hazardous.

Communicating Safety and other Lab Issues

You should report any procedure, condition or situation that you consider to be unsafe, or potentially unsafe. Except for an actual emergency, the best way to communicate a safety problem is to write an email to Kai Ewert or Youli Li (or Amanda Strom), depending on the nature of the problem. Forms for anonymously reporting a hazardous condition or practice (Hazard reporting forms) are available at the MRL Safety Corner bulletin board in room 2042 if you feel that reporting the hazard in the usual manner would jeopardize you in some way.

If supplies are missing, a hazardous waste pickup needs to be arranged, or a piece of equipment is not working, contact the responsible lab member (the current list of responsibilities/chores is posted in the lab).

Personal Protective Equipment (PPE)

The following summarizes the requirements (as per UC and MRL policy) about personal protective equipment, i.e., equipment designed to protect workers from laboratory hazards. For quick reference, each laboratory door displays a poster summarizing the UC policy on PPE.
Specific procedures may require specialized protective equipment; for example, you must wear the specialized safety glasses with darkened glass when flame-sealing capillaries for X-ray experiments, and use insulated gloves when handling items in the -70 °C freezer.
You are not allowed to purchase your own PPE. PPE will be provided by UCSB or the laboratory.

Safety Glasses and Other Eye Protection

Safety glasses must be worn at all times when working in an MRL laboratory. Please read the article by double-Nobel laureate K. B. Sharpless in Appendix I to emphasize the importance of eye protection in the laboratory. Even if you are not working with hazardous materials, someone else in the lab probably is. All eye protection equipment must be American National Standards Institute (ANSI) approved and appropriate for the work being done. The two exceptions to the requirement for safety glasses for our lab are the “LOM area” between 1012 and 1024, which is not a lab space, and when doing microscopy.

Each member of the lab should have their own, personal pair of safety glasses. Regular corrective lenses or sunglasses are NOT safety glasses, nor do contact lenses provide any sort of adequate protection. Increase the likelihood of wanting to wear your safety glasses by getting a pair that is comfortable and keeping them clean and scratch-free, so your vision is as good with as without them. Safety glasses will be part of the PPE you are given when you begin work in the laboratory. You can also get safety glasses in the storerooms, by ordering from Fisher, or by taking one of the spare pairs (see below).

Spare / extra safety glasses and some specialty safety glasses are in the top drawers of the cabinets located on your left as you enter room 1012.

Face shields (for splash protection) are kept on the side of the single hood in room 1024 (see “Communal PPE” below).

Clothing requirements

Full-length pants, or equivalent, must be worn at all times while working in or occupying any laboratory area (i.e., legs must be covered by clothing). The area of skin between the shoe and ankle should not be exposed.
The MRL recommends that lab users wear non-synthetic (cotton) clothing. Cotton (or other non-synthetic material) clothing is mandatory (underneath a flame-resistant lab coat) when working with highly flammable liquids or pyrophorics, to minimize injury in the case of a fire emergency.

Closed-Toe Footwear

Closed-toe footwear must be worn in the lab at all times!

Lab coats

Laboratory coats are required to be worn while working on, or adjacent to, all hazardous chemicals, biological or unsealed radiological materials. It is imperative to consider the nature of the work performed when choosing a lab coat. In general, you must wear a flame-resistant (blue) lab coat when working in the Main MRL Labs, and a regular lab coat or a lab coat with elastic cuffs when working in the Cell Lab. Do not wear lab coats in the LOM. Only use the lab coats that you have been issued; “standard” labcoats are typically made from a polyester/cotton mix and are not suitable for work with flammables.

Laboratory coats must not be worn outside of a laboratory unless the individual is traveling directly to an adjacent laboratory work area.

Each person should have their personal lab coat, which they will receive as part of the PPE provided by UCSB to new lab workers. These laboratory coats must be appropriately sized for the individual and be buttoned to their full length. Laboratory coat sleeves must be of a sufficient length to prevent skin exposure while wearing gloves. Some spare lab coats are available in the lab if needed, check with Kai Ewert.

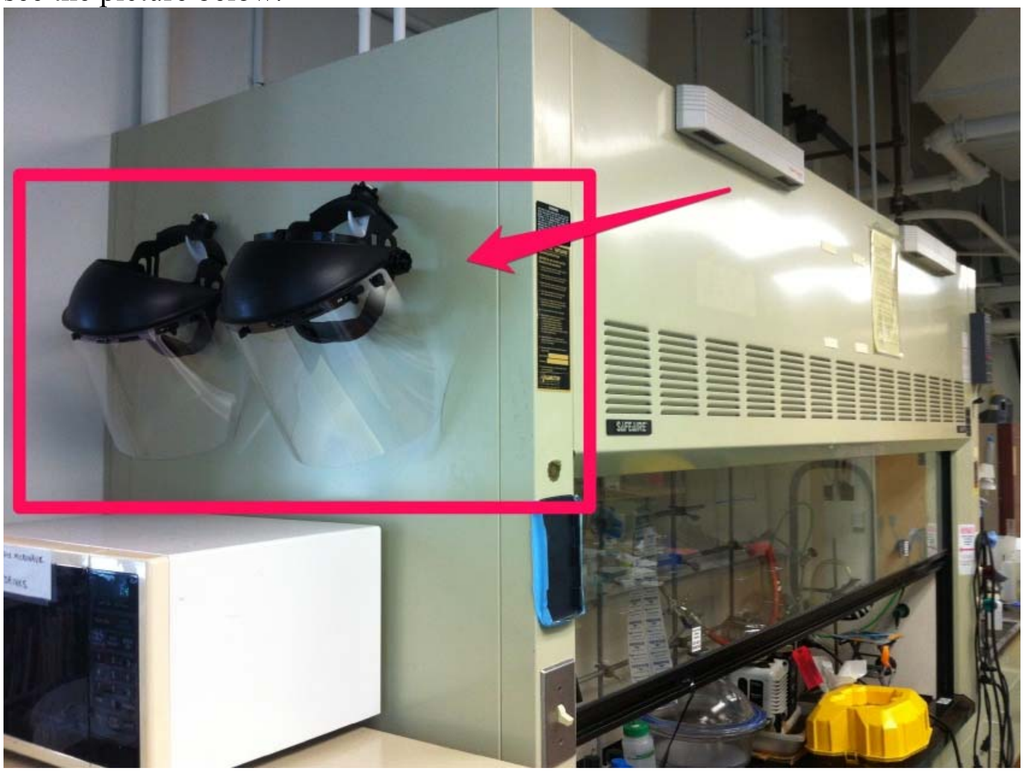
Lab coats must not be cleaned at home or in public laundry facilities. Rather, a professional cleaning service must be used. See the information at the lab coat laundering drop off station in the MRL (near the restrooms on the first floor). Any clothing that becomes contaminated with hazardous materials must be decontaminated before it leaves the laboratory. If a lab coat is heavily contaminated, it should be packaged safely and disposed of as hazardous waste.

Communal PPE

Certain PPE items are used so rarely that they are not handed out to each individual lab member. Rather, they are available to everyone as communal PPE in the lab. These items and their locations are as follows:

- **Splash apron**
  A splash apron, for body protection against splashes (to be used when handling very large volumes of hazardous liquids or for other procedures with high splash potential), is kept next to the door from room 1024 to the hallway (on your right as you enter the lab) – see the picture below.

- **Face shields**
  Face shields, for eye and face protection from splashes, are kept on the side of the single hood in room 1024 (on your left right as you enter 1024 from the LOM) – see the picture below.



Gloves

Protective gloves must be worn while utilizing any hazardous chemical, biological or unsealed radiological material. These gloves must be appropriate for the material being used and conditions under which such use takes place (e.g., extreme cold).

Educate yourself as to which chemicals the gloves you are using are resistant and (im)permeable to. You may be unpleasantly surprised. However, there is a **tradeoff** between chemical resistance of gloves and the dexterity they allow. The increased dexterity offered by thinner gloves may offset their poorer chemical resistance. After all, it is safest not to spill anything in the first place! The latex or nitrile (purple) single-use examination gloves readily available in our lab are a good choice for most powders and for aqueous solutions, as well as simple alcohols (such as methanol, ethanol, and isopropanol) and diethyl ether.

EH&S has a page with information on gloves, including links to several reference charts with compiled data on chemical resistance of lab gloves at
https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp/sec2/selecting-proper-gloves

On the following pages, you can find information and a **table with resistance data** for common laboratory gloves (nitrile, latex, and neoprene gloves are available in the lab or from the campus storerooms). This table is the one which makes the most sense from a chemical intuition point of view. Be careful trusting any of these charts and remember that the best protection is to not spill anything in the first place! (Text and chart downloaded on Aug 14, 2014 from

http://www.allsafetyproducts.com/glove-selection-chart-chemical-breakthrough-ratings.html; now at http://www.allsafetyproducts.com/asp-glove-selection-chart-chemical-break-through-times.html)

If you are working with **pyrophoric chemicals**, you must wear kevlar liners under neoprene gloves. No other gloves or glove combination is acceptable. A supply of both the liners and the gloves is available in the cupboards containing spare PPE in room 1032 or from the chemistry storeroom.

There are several places in the lab where we keep latex and nitrile single use examination gloves. While impermeable to water, buffers, acids and bases, neither of these gloves are very impermeable to most solvents. This means that you should *immediately* and *quickly* remove the gloves if you spill solvent on them. For increased safety, you might want to wear two pairs of gloves on top of each other. This will slow the permeation through the gloves down somewhat. Extremely impermeable (and clumsy) "barrier" gloves are available from the Physics storeroom. The single-use gloves are available from the storerooms or via Fisher.

You must take off your gloves as soon as you are no performing lab work, e.g. when you answer the telephone, operate a door handle or use a computer keyboard in the lab. As mentioned above, the "LOM area" is the only area where food and drink may be kept and eaten. This is why you *must take off your gloves* when doing anything in the LOM (e.g. using the computer).

Gloves for protection from heat and cold are also available in the lab, usually next to the ovens and the -70 °C freezer.

Glove Selection Chart with Chemical Breakthrough Ratings

The glove selection chart below is provided by All Safety Products as a general guide for glove selection in relation to chemicals handled. Glove performance varies between manufacturers, so always give yourself extra time and do not push glove strength to the estimated limits.
Many factors affect the breakthrough times including, but not limited to:

1. Thickness of glove material
2. Concentration of the chemical worked with
3. Amount of chemical the gloves come in contact with
4. Length of time which the glove is exposed to the chemical
5. Temperature at which the work is done
6. Possibility of abrasion or puncture.

Chemical Resistance Chart

This Chemical Resistance Chart is intended to provide general information about the reactions of different glove materials to the chemicals listed. SAS Safety gloves have not been individually tested against these chemicals. Variability in glove thickness, chemical concentration, temperature, and length of exposure to chemicals will affect the performance.

Key: P=Poor, F=Fair, G=Good, E=Excellent, NR=Not Recommended

Chemical	Neoprene	Nitrile	Latex	PVC
Acetaldehyde	E	P	F	NR
Acetic Acid	E	G	G	F
Acetone	G	NR	G	NR
Acetonitrile	F	NR	F	NR
Ammonium Hydroxide<30%	E	E	G	E
Amyle Acetate	NR	E	F	P
Amyl Alcohol	P	G	G	NR
Aniline	G	NR	P	F
Animal Fats	E	E	P	G
Battery Acids	E	E	G	E
Benzaldehyde	NR	NR	F	NR
Benzene	NR	P	NR	NR
Benzoly Chloride	NR	NR	P	NR
Butane	F	E	P	P
Butyl Acetate	NR	F	P	NR
Butyl Alcohol	E	P	E	G
Butyl Cellusolve*	E	E	E	NR
Carbon Acid	E	P	P	G
Carbon Disulfide	NR	NR	NR	NR
Carbon Tetrachloride	P	G	NR	NR
Castor Oil	E	E	E	E
Cellosole Acetate	E	G	G	NR
Cellosole Solvent	E	G	E	NR
Chlorobenzene	NR	NR	NR	NR
Chloroform	F	F	NR	NR
Chloronaphalens	NR	F	NR	NR
Chloroethene VG	NR	F	NR	P
Chromic Acid	F	F	NR	G
Citric Acid	E	E	E	E
Cottonseed Oil	E	E	P	G
Cresols	G	G	P	F
Cutting Oil	E	E	F	P
Cyclohexane	F	E	P	P
Cyclohexanol	E	E	P	G
Dibutyl Phthalate	F	G	P	G
Diethylamie	P	F	NR	NR
Di-Isobutyl Ketone	P	E	P	P
Dimethyl Formamide (DMF)	G	NR	E	NR
Dimethyl Sulfoxide (DMSO)	E	E	E	NR
Dicotyl Phthalate (DOP)	G	G	P	NR
Dioxane	NR	NR	NR	NR
Ethyl Acetate	F	NR	P	NR
Ethyl Alcohol	E	E	E	G
Ethylene Dichloride	NR	NR	P	NR
Ethylene Glycol	E	E	E	E
Ethyl Ether	E	E	NR	NR
Ethylene Trichloride	P	P	P	NR
Formaldehyde	E	E	E	E
Formic Acid	E	F	E	E
Freon	G	F	NR	NR
Furfural	G	NR	E	NR
Gasoline	P	E	NR	P
Gylcerine	E	E	E	E
Hexane	E	E	NR	NR
Hydraulic Fluid Petro. Based	F	E	P	G
Hydraulic Fluid Easter Based	P	P	P	P
Hydrazine 65%	E	E	G	E
Hydrochloric Acid*	G	E	E	E
Hydrofluoric Acid	G	E	E	E
Hydrogen Peroxide	E	E	E	E
Hydroquinone	G	E	E	E
Isobutyl Alcohol	E	E	E	F
Iso-Octane	E	E	NR	P
Isopropyl Alcohol*	E	E	E	G

Chemical	Neoprene	Nitrile	Latex	PVC
Kerosene	E	E	P	F
Lactic Acid	E	E	E	E
Lauric Acid	E	E	G	F
Linoleic Acid	E	E	P	G
Linseed Oil	E	E	P	E
Maleic Acid	E	E	P	G
Methyl Acetate	G	P	P	NR
Methyl Alcohol	E	E	E	G
Methylamine	G	E	E	E
Methyl Bromide	NR	NR	NR	NR
Methylene Chloride	NR	NR	NR	NR
Methyl Cellusolve	E	F	P	-
Methyl Ethyl Ketone (MEK)	G	NR	G	NR
Methylisobutyl Ketone	NR	P	F	NR
Methyl Methacrylate	NR	P	P	NR
Mineral Oil	E	E	P	F
Mineral Spirits	G	E	NR	F
Monoethanolamine	E	E	G	E
Morpholine	P	NR	G	NR
Muriatic Acids	E	G	G	G
Naptha V.M & P.	G	E	NR	P
Nitric Acid <30%	E	P	G	G
Nitric Acid 70%	G	NR	F	F
Nitrile Acid Red Fuming	NR	NR	P	P
Nitrile Acid White Fuming	NR	NR	P	P
Nitrobenzene	NR	NR	P	NR
Nitromethane	E	F	G	P
Nitropropane	G	NR	E	NR
Octyl Alcohol	E	E	G	F
Oleic Acid	E	E	P	F
Paint Remover	G	G	F	P
Palmitic Acid	E	G	G	G
Pentachlorophenol	E	E	P	F
Pentane	E	E	P	NR
Perchloric Acid 60%	E	E	P	E
Potassium Hydroxide <50%*	E	G	E	E
Printing Ink	G	E	G	F
Propyl Acetate	P	F	P	NR
Propyl Alcohol	E	E	E	F
Perchloroethylene	NR	G	NR	NR
Phenol	E	NR	G	G
Phosphoric Acid*	E	E	G	G
Picric Acid	E	E	G	E
Propylene Oxide	NR	NR	P	NR
Rubber Solvent	G	E	NR	NR
Sodium Hydroxide <50%	E	G	E	G
Stoddard Solvent	E	E	P	NR
Styrene*	NR	NR	NR	NR
Sulfuric Acid 95%	F	G	NR	NR
Tannic Acid	E	E	E	E
Tetrahydrofuran (THF)	NR	NR	NR	NR
Toluene	P	G	NR	NR
Toluene Di-Isocyanate (TDI)	NR	NR	P	P
Trichlorethylene (TCE)	P	G	NR	NR
Triricrestyl Phosophate (TCP)	F	E	G	F
Triethanolamine 85% (TEA)	E	E	G	E
Tung Oil	E	E	NR	F
Turbine Oil	E	G	P	F
Turpentine	G	E	P	P
Vegetable Oil	E	E	P	F
Xylene	P	G	NR	NR

***Warning:** Protective gloves and other protective apparel selection must be based on the user's assessment of the workplace hazards. Glove and Apparel materials do not provide unlimited protection against all chemicals. It is the user's responsibility to determine before use that the Glove and Apparel will resist permeation and degradation by the chemicals (including chemical mixtures) in the environment of intended use. Failure by the user to select the correct protective gloves can result in injury, sickness, or death.

AllSafety products

Chemical Resistance Chart

The Laboratory Hazard Assessment Tool ("LHAT")

Before beginning work in the lab, you will have to use the LHAT to learn about the hazards in the labs you will use and the required PPE. The LHAT is a web-based system intended to identify and communicate hazards present in a lab or research area. Once hazards are identified, lab members can take appropriate Personal Protective Equipment (PPE) training and receive PPE appropriate for their work. You can log in to LHAT at

https://ehs.ucop.edu/

Because of the different hazards present in them, the Safinya labs in the MRL are divided into three sections in LHAT: the Main MRL Labs, the Cell Lab, and the LOM. For reference, the certified laboratory hazard assessments for the three labs (current as of May 16, 2022) are attached to this CHP as Appendix F. The recommended PPE for the three labs is listed below.

Main MRL Labs

Personal Protective Equipment	Custom Laboratory Activity PPE	Shared Protective Equipment
• Closed toe/heel shoes • Full-length pants or equivalent • Chemical splash goggles • Safety glasses • Lab coat • Flame resistant lab coat (NFPA 2112)		• Flame-resistant (FR) outer gloves • Chemical-resistant apron • Face shield • Disposable gloves • Thermal protective gloves (impermeable insulated gloves for liquids and steam) • Cryogenic protective gloves • Shoe covers • Possibly warm clothing • Optical density and wavelength-specific safety glasses based on individual beam parameters • Chemical-resistant gloves • Cut-resistant gloves • Impermeable or chemical resistant gloves

Notes:

- In all cases, chemical splash goggles can be substituted for safety glasses and provide a higher level of protection when working with large quantities of material. For splash or impact protection, either chemical splash goggles or safety glasses need to be worn under face shields.

Cell Lab

Personal Protective Equipment	Custom Laboratory Activity PPE	Shared Protective Equipment
• Closed toe/heel shoes • Full-length pants or equivalent • Chemical splash goggles • Safety glasses • Lab coat • Barrier lab coat impervious to fluids		• Double layer disposable gloves • Face shield • Disposable gloves • Eye and mucous membrane protection (as appropriate for operations) • Thermal protective gloves (impermeable insulated gloves for liquids and steam) • Cryogenic protective gloves • Chemical-resistant gloves • Cut-resistant gloves

Notes:

- In all cases, chemical splash goggles can be substituted for safety glasses and provide a higher level of protection when working with large quantities of material. For splash or impact protection, either chemical splash goggles or safety glasses need to be worn under face shields.

LOM area

No PPE is recommended. This laboratory has been designated and posted as free of chemical, physical, biological, radiological, laser, and non-ionizing hazards.

Fridges and Freezers

There are a number of fridges and freezers in the lab. Only one of them (across from the fume hood in 1012) is designed for the storage of flammables. This (clearly labeled) fridge is the only fridge where flammable liquids may be stored, and its use for items that do not require a fridge that is designed for storage of flammables should be minimized.
No food or drink must be stored in any of the fridges in the lab.
Take care when using the -70 °C freezer in 1032. Always wear the appropriate insulated gloves (typically stored on top of the freezer) to avoid frostbite or your fingers getting stuck to contents in the fridge or its walls. Minimize the time that this freezer is opened, as moisture from the air rapidly condenses on it.

Some Best Lab Practices

These make the lab a better place to work for everybody:

- Return 4 L solvent bottles to the storage cabinet at the end of the day. Don't leave them in the hood or on the bench top
- Put your reagents back in the proper storage location at the end of every workday
- Refill squirt bottles when they are nearly empty
- Get new solvent bottles from the storeroom before running out
- Empty rotavap solvent traps when you are done
- Label all your bottles/flasks with proper chemical names. Preferably use pencil on tags, not a marker
- Label all running reactions, especially reactions running overnight
- Scales/Scale areas: Keep the scale and surrounding area clean. After weighing, take all your stuff with you, and completely clean up any spills you made. Put a note on the scale if you need the tare to remain set; only do this if you will return after a short time (< 15 minutes), else record the tare weight.
- Close the regulator on gas tanks once you are done using them
- Don't leave samples, lab supply, personal effects, glassware, books or papers out in the lab except when you are actually using them
- Wash and put away your glassware everyday
- Before purchasing new chemicals be sure to check if any of the required reagents are available in the lab

Using Eppendorf-type pipettes:

To increase the accuracy of your experiments as well as the lifetime of these expensive instruments, follow the simple guidelines below.

- Only the pipette tip and *never* the shaft is immersed in the solution being aliquoted from. If at any point in time you do contaminate the shaft either during sample aspiration, or by placement of the pipette into the solution, clean the shaft immediately. The shaft must be clean to prevent sample cross-contamination and corrosion of the metal tip ejector

- The different pipette types (regular vs. trigger) each require specific pipette tips. If the tip doesn't fit right, sample aspiration is inaccurate

- *Never* adjust the pipette volume above the designated upper limit or below the lower limit; not only are the pipettes inaccurate outside of the designated range, this also damages the instrument. The following are the upper and lower limits for each pipette:

P2:	0.1uL – 2µL
P10:	0.5uL – 10µL
P20:	2uL – 20µL
P200 (trigger):	20uL – 200µL
P200 (general):	50uL – 200µL
P1000:	200uL – 1000µL

- If a specific pipette is not in full working order (e.g. the thumbwheel does not move smoothly, the pipette is not aspirating the correct volume, the tip ejector is corroded) contact the lab member responsible for the maintenance of the pipettes right away

- When using these pipettes to measure organic solvents, special considerations apply. The relatively high vapor pressure of many common organic solvents (e.g. methanol, chloroform) can result in buildup of pressure after the solvent is aspirated. This leads to dripping (which also tends to be more pronounced due to the lower surface tension (compared to water) of these solvents), and therefore to volume inaccuracies. Aspirating and ejecting a few times before transferring the liquid usually solves this problem. Another potential problem is the lack of resistance of plastic tips to organic solvents. Only polypropylene tips must be used, and the time of contact between solvent and tip material must be minimized to avoid contamination.

Labeling of Samples, Solutions etc.

As a general rule, all samples, custom-made solutions, etc. must be labeled with the name of the owner, date prepared, and complete chemical name(s). While this ideal may not always be achievable, the absolute minimum (e.g. for small containers) is to label the holder / large container with the name of the owner, the date and if applicable information about any particular hazards (e.g. “ethidium bromide – highly toxic”). The more hazardous the material and the longer the container will be around, the more complete the labeling must be. If necessary, use a labeled sample holder or secondary container that is more completely labeled. This also has the advantage that it can be reused for similar samples at a later point.

It is best practice to label containers containing purchased chemicals with your initials, date received, and date opened (e.g. "KE Rcd. 9/09, Op. 10/09"). See also the SOP on Chemical Storage, in particular the information on time-sensitive chemicals.

Lab Safety Equipment

Below are the locations of emergency showers and eyewash stations in the lab as well as basic directions for their use.

Emergency Showers and Eyewash Stations

Outside of the doors of rooms 1012 and 1024 are emergency showers with eyewash stations. Most of the sinks also have some setup that may be used as an improvised eyewash station. Do not use the emergency showers unless there is an actual emergency. Facilities management (x8300) needs to be called to turn them off once activated.

If a chemical splashes in someone's eye, rinse with copious amounts of water **for a minimum of 5 minutes**. Small burns or splashes with corrosive chemicals on the skin are also flushed with water for five minutes as a first aid measure. Use the emergency showers if a person's hair or clothing has caught fire (rolling the person on the floor is another option for extinguishing flames) or in the event of a larger spill of a hazardous chemical on skin or clothing.

Spills and Exposure to Hazardous Chemicals

For all incidents in which injury has occurred or may be imminent, follow the steps below.

Emergency procedure

- Evacuate the area if needed for safety
- Administer First Aid as needed
- Warn people in the area
- Notify emergency services (call 9-911 from campus phones, or 805 893 3446 from cell phones[2])
- Notify Kai Ewert as soon as feasible

First Aid After Exposure to Hazardous Chemicals

If a chemical splashes in someone's eye, rinse with copious amounts of water **for a minimum of 5 minutes**. Small burns or splashes with corrosive chemicals on the skin

[2] simply calling 911 from a cell phone will not contact UCSB dispatch, but rather the Ventura dispatch, possibly causing delays

are also flushed with water for five minutes as a first aid measure. Use the emergency showers if a person's hair or clothing has caught fire (rolling the person on the floor is another option for extinguishing flames) or in the event of a larger spill of a hazardous chemical on skin or clothing.

Spill Cleanup

See the SOP on Chemical Spill Cleanup for information on when and how to clean up a chemical spill (page 115).

Disposal of Hazardous Waste

To prevent injury, minimize environmental health hazards, and meet regulatory requirements, all hazardous waste must be disposed of in compliance with UCSB chemical waste disposal procedures. Individuals may be held criminally liable for violations of applicable laws and regulations.

An online refresher course on hazardous waste is available (course code EH23) at the UC Learning Center:

https://www.learningcenter.ucsb.edu/

Chemical Waste Disposal

Do not dump any hazardous substances down the drain!!!
Do not dispose of chemicals in trash cans.

Do not leave chemical waste in open containers in the fume hood. Waste containers must be capped if not in use. Note that the cap on the Acid Waste container in the lab should only be loosely tightened to prevent the buildup of pressure. Do not use fume hoods to intentionally evaporate chemicals.

See also the EH&S Fact Sheet on Chemical Waste in Appendix A.

Proper Hazardous Waste Segregation

The lab's chemical waste is segregated in order to avoid violent reactions of incompatible chemicals. If you are not absolutely sure about where your specific waste can and needs to go, contact Kai.

- We segregate halogenated and nonhalogenated solvent waste. The following solvents and mixtures containing them must only be added to the "Halogenated Solvent" waste:
  - Chloroform
  - Dichloromethane
  - Anything with "chloro", "bromo", or "fluoro" in the name – ask Kai if you are unsure.

See below for a picture of the bottles for collecting chemical waste that mainly consists of organic solvents:

(Note that red color marks nonhalogenated waste, while blue color marks halogenated waste)

Fire and explosion hazard: Under no circumstances may organic material (e.g. solvents) be added to the acid waste (clear bottle with yellow color markings).

This is the bottle for acid waste

(Note that it is clear and has yellow and black color markings)

- Segregate solids from liquids if feasible

- If your waste falls in one of the following categories (or you are not sure whether it does), request that a new collection container be started for it (contact Kai or the lab member responsible for chemical waste):
    - Strong oxidizers
    - Peroxide-forming chemicals
    - Cyanides
    - **Alkaline solutions of pH > 12.5**
    - Chemical carcinogen
    - Alkali metals and other water reactives
    - Unstable chemicals
    - Heavy metal solutions and salts
    - Other toxic materials

Collecting and Storing Hazardous Waste

Chemical waste must only be stored in the lab's designated Hazardous Waste Storage Area in one of the hoods in room 1024

When adding waste to the common collection bottles (solvent wastes, acid waste), please make sure to enter the amount and composition of your waste on the provided lists.

Other chemical waste storage requirements:

- Store chemical waste in appropriate containers (containers designed for storage of chemicals). Suitable empty bottles (4 L solvent bottles) are stored on a shelf next to the door to the confocal microscope hutch (room 1032). Check with Kai for smaller bottles.
- Containers must be completely sealed to prevent spillage. Remember, however, that the cap on the Acid Waste container should only be loosely tightened to prevent the buildup of pressure.
- Liquid waste must be in screwtop containers, and the containers must not be filled over 80%.
- Outside surfaces of containers must be clean and free of contamination.

Labeling Hazardous Waste

Use the official UCSB hazardous waste labels and provide all the requested information. Labels are available for free in the storerooms, and we usually have a stock of these labels at hand in the cabinet above the cleaning bath in 1012.

- Waste must be identified by chemical name (no abbreviations)
- All constituents in solid and liquid mixtures must be identified, and their concentrations stated to the extent possible
- Identify the chemical hazard classification(s) of the waste (e.g. flammable, corrosive, oxidizer, etc.)
- Any original/existing labels must be defaced by either removal or lining out

- Date containers. Hazardous waste containers must be disposed of in a timely manner. Under no circumstances must hazardous waste containers be stored for more than 9 months

Proper Waste Disposal / EH&S Pickup

Whenever a waste container is about 75% full, notify the group member responsible for waste disposal or Kai so that pickup by EH&S can be arranged.

To electronically request pickup of the waste by EH&S, visit

http://ehs.ucsb.edu/hazwasterequest

Notes:

- EH&S cannot accept responsibility for improperly labeled, packaged, and/or segregated chemicals, and **will not pick them up**
- Waste containers become the property of EH&S and will not be returned

Sharps disposal

Sharp materials (such as broken glass, razor blades, or hypodermic needles) must not be placed in the regular lab trash as this could injure the custodian. See below for proper disposal procedures. Depending on their size, other sharp materials may be disposed as described for broken glass (large items) or needles and razorblades (small items).

Glass Disposal

All glass (except recycling) must go into the designated glass disposal containers in the lab. These are white and blue cardboard boxes with a plastic lining.

When the container is full: take the lid off, flip the cover over the opening and place the lid back on the container. Then use duct tape to secure the lid and to prevent the container from rupturing during handling. Finally, dispose of the container in one of the designated red-lidded “Sharps” bins (the closest ones are next the the MRL gas cage at the back of the MRL and across from the Physics machine shop at the front of the MRL); you may need a key to open these bins—this is kept on top of the toolbox in room 1012. New glass disposal containers are available, e.g., from the physics storeroom or from Fisher.

Disposal of Razor Blades, Needles, etc.

Our lab has a supply of plastic containers specifically designed for the disposal of razor blades and hypodermic needles. Typically, one of these is available in the hood next to the sink in room 1024. A supply of these containers is in a drawer next to the sink in 1024. When the container is full, close the lid tightly (it should snap into place), secure with duct tape, place in the storage area for hazardous waste and request pickup by EH&S with their online form.

Completing Work in the Lab – A Checklist

On finishing your work and your stay in the Safinya Lab at UCSB, you will need to make way for the next person and put your gear back into circulation. Please do the following:

Get Started

- ☐ Let Kai know when you are leaving a few weeks before you are gone. He'd much rather help you clean if you feel you don't have sufficient time just before you leave then discover unlabeled samples/chemicals a few years down the road

Get Clear

- ☐ Properly dispose of any pyrophoric and/or water-reactive materials that you ordered, unless cleared to do otherwise by Kai Ewert. Contact Kai for help with proper disposal.
- ☐ Dispose of most of your samples (don’t forget about your microscopy samples if you have them). A select few may be archived
  - o Consider whether anybody will really ever want to look at the samples again. Almost none of the current old sample archive has ever been accessed by anybody
- ☐ For samples to be archived:
  - o Label these samples extra-well
  - o place them in the smallest cardboard box possible
  - o write your name prominently on the outside along with basic info about the samples
  - o place a spreadsheet detailing what the samples are in that same box
  - o add a large-lettered note on top of the box identifying any hazardous materials in the box / the samples
  - o store the box as the samples dictate (lab, fridge, or freezer)
- ☐ Put “personal” chemicals, labware, capillaries back into circulation
- ☐ Clear and clean your bench space
- ☐ Clear out your personal drawers in the lab. Any equipment that has been assigned to you should be put back into circulation
- ☐ Clear out your items in the fridge(s)
  - o Main fridge
  - o Cell lab fridges / Protein fridge
- ☐ Clear out your items in the freezer(s)
  - o Regular freezer
  - o Lipid freezer / -70°C Freezer
- ☐ Clear out your items in the cell lab
- ☐ Any reagents in your possession should go back to the appropriate chemical storage area or to someone in the group

- □ Make sure all waste you have generated is transferred to the waste storage area in accordance with the lab's waste disposal procedures
- □ Archive the data on your computer and also leave it in its original place
- □ Hand your labbooks over to the person continuing work on your project, or archive them on the shelves in room 1032
- □ Go through the shelves, cabinets, and drawers in your office and take, pass on, or dispose of all that's yours

Stay Connected

- □ Give Kai your new contact information, most importantly a permanent email address – both for the alumni webpage and to enable future lab members to contact you about your work here. You may also want to connect on LinkedIn, which makes it easy to stay in touch and for us to keep up to date with your post-UCSB career.

Standard Operating Procedures (SOPs)

Standard Operating Procedure General Information

The following apply to all chemicals unless specifically noted in the customized SOP. Any additional requirements will also be noted in the SOP:

Engineering Controls:

Fume Hood: All chemicals should be transferred and used in an annually certified chemical fume hood, in an effort to keep exposures as low as possible. If your specific protocol does not permit the handling of certain chemicals in a fume hood, contact EH&S to determine whether additional *respiratory protection* and/or *specialized local ventilation* is warranted.

Safety Shielding: Shielding is required of there is significant risk of explosion, implosion or splash. This risk can be due to the nature of the chemicals involved, the reaction conditions (temperature, pressure) or scale.

Storage: All chemicals should be stored upright, tightly sealed, and in a cool, dry, and well ventilated space. Segregate incompatible materials from each other based on information from the SDS and as described in the Chemical Hygiene Plan. All containers must be labeled in English with the name of the material (no formulas or acronyms) and all relevant hazard statements (e.g. corrosive, flammable, etc.)

First Aid and Emergencies:

Fire: DO NOT use water to put out a fire. A class ABC fire extinguisher can be used to extinguish most laboratory fires. If pyrophoric or water reactive metals are involved in the fire, use a class D extinguisher.

Spills: Evacuate the location where the spill occurred. Notify others in the areas of the spill, including your supervisor. Notify EH&S in case of personal exposure. If the spill is <1 Liter and of a known material of limited toxicity, flammability and volatility, post someone just outside of the spill area, don proper PPE, and clean the spill following the procedure in the Chemical Hygiene Plan Chapter 4 and the UCSB Emergency Flip Chart. Otherwise, call EH&S at x3194, or 911 if there is immediate danger to life, health or property.

Exposures:

Skin or eye contact: Remove contaminated clothing and accessories. Flush affected area with water for 15 minutes. If symptoms persist, get medical attention.

Inhalation: Move person to fresh air. If symptoms persist, get medical attention.

Ingestion: Rinse mouth with water. If symptoms persist, get medical attention.

Decontamination: Wear proper PPE, decontaminate equipment and benchtops using soap and water. Dispose of contaminated paper towels as hazardous waste, following the UCSB hazardous waste procedures described in the UCSB Chemical Hygiene Plan.

Waste Disposal: Refer to Chapter 3 of the UCSB Chemical Hygiene Plan.

Background: Standard Operating Procedures

Per the OSHA Standard, a complete CHP includes **Standard Operating Procedures (SOP)** to aid workers in minimizing chemical exposures in the lab**.** This is generally interpreted to mean SOPs for the following – **not** for all possible chemical operations:

- Operations involving Particularly Hazardous Substances (PHS), namely, **"Select" Carcinogens**, **Highly acute toxins**, and **Reproductive toxins** (for a list, see https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp/sec3/particularly-hazardous-substances)
- Other "high-hazard" chemical operations

It is the responsibility of lab supervisors to develop new SOPs (or augment the generic PHS SOP) if needed to protect their workers. The decision on whether a specific SOP is required is the prerogative, but also the responsibility, of the lab supervisor.

Standard Operating Procedure Library Certification

PI/Laboratory Supervisor Name: **C. R. Safinya**

Applicable Laboratory Locations (Building, Room #):

MRL (615), rooms 1012, 1012B, 1016, 1024, 1032

PI/Laboratory Supervisor Signature:

I certify that I have reviewed and approve the Standard Operating Procedures contained in the following sections of this Laboratory Specific Chemical Hygiene Plan for laboratory operations being conducted in the locations noted above.

___________________________ (C. R. Safinya) _______________ Date

SOP: Use of Acrylonitrile

NOTE: Acrylonitrile (aka vinyl cyanide, ACN) is classified as a Particularly Hazardous Substance (PHS) per Cal-OSHA, since it is listed as a **"Select" Carcinogen**.

Date of last revision to SOP: Aug. 2014 – Kai Ewert

Scope of SOP

Use of acrylonitrile in chemistry procedures in the lab

Compound information

Acrylonitrile (also called vinyl cyanide) is a highly flammable chemical. It is toxic if inhaled, ingested or absorbed through skin. It can undergo explosive polymerization when exposed to heat, light, strong acid, or strong bases. It can form explosive mixtures with air or other strong oxidizers. See the appended LCSS for more information.

Components of the hazardous decomposition of acrylonitrile exposed to fire include carbon oxides, nitrogen oxides, and hydrogen cyanide.

Acrylonitrile is toxic if inhaled; it is extremely destructive to the tissue of the mucous membranes and upper respiratory tract. It may cause allergy or asthma symptoms, breathing difficulties, or respiratory irritation if inhaled. It may be fatal if absorbed through skin. Causes skin burns. Causes eye burns. Toxic if swallowed. A potential carcinogen.

Approval Required

Anyone working for the first time with acrylonitrile in this laboratory must consult with Dr. Kai Ewert. Users must study the relevant safety information and be aware of the appropriate waste disposal method (via non-halogenated solvent waste).

General precautions

Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor or mist. Wash hands before breaks and immediately after handling acrylonitrile.

Personal Protective Equipment

Users of acrylonitrile shall employ the following:

- **Protective eyewear**

ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. For procedures with splash potential, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

Use of a flame-resistant ("blue") lab coat is mandatory, as are long pants and closed-toe shoes.

- **Lab gloves**

Standard latex or nitrile gloves do not provide adequate protection from acrylonitrile spills. As per UCSB EH&S, only Butyl and Viton gloves offer protection, but "Barrier" type gloves should also work. A small stock of "Barrier" type gloves is usually at hand in the cabinet in room 1032; these gloves are also available from the Physics storeroom. Wash hands after use of acrylonitrile.

Engineering/Ventilation Controls

Acrylonitrile must be handled in a **fume hood**. Use on the open bench is prohibited.

When outside of the fume hood, containers must be sealed. The use of acrylonitrile on an open lab bench, in open containers, will likely result in worker exposures above the Cal-OSHA legal/safe limits for acrylonitrile.

Handling, Storage, Cleanup, First Aid, and Disposal Requirements

- **Handling:**

Work with acrylonitrile must be performed in the laboratory fume hoods. Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor or mist. Wash hands before breaks and immediately after handling the product. Acrylonitrile is a highly flammable liquid and vapor that should be kept away from heat, sparks, open flames, and hot surfaces. Wash hands after use of acrylonitrile.

- **Storage:**

Acrylonitrile must be stored in completely-sealed containers in one of the "Flammables" storage cabinets underneath the fume hoods or in the fridge approved for storage of flammables. Store in the dark or protect from light with aluminum foil. If possible, use original container for storage.

- **Spills/Cleanup:**

Spills of acrylonitrile must be cleaned up as rapidly and completely as possible. Assess the extent of danger. Help contaminated or injured persons. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
Place leaking containers in a fume hood. If it can be done safely, clean up small spills with absorbent material (e.g. paper towels) and collect all contaminated materials (including gloves) in a tight-closing container. Make sure to wear "Barrier" type gloves if cleaning up a acrylonitrile spill. A small stock of "Barrier" type gloves is usually at hand in the cabinet in room 1032; these gloves are also available from the Physics storeroom. For larger spills that can not be safely and completely handled by lab personnel, leave the area and contact EH&S at x3194. Follow the procedures for emergencies outlined in the beginning of the CHP and in the SOP for chemical spills.

- **First Aid:**

Call 9-911 (from campus phones, else 911) for immediate medical attention.

If inhaled
Move person into fresh air. If not breathing, give artificial respiration. Consult a physician.
In case of skin contact
Take off contaminated clothing and shoes immediately. Wash skin with soap and plenty of water. Use the lab emergency shower/eyewash or a faucet as appropriate. Take victim immediately to hospital. Consult a physician.
In case of eye contact
Check for and remove any contact lenses. Rinse thoroughly with plenty of water for at least 15 minutes (lifting upper and lower lids occasionally). Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician. Continue rinsing eyes during transport to hospital.
If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

- **Disposal:**

All acrylonitrile wastes must be disposed of through EH&S as non-halogenated solvent waste. No acrylonitrile must go into the sewer system, trash or be allowed to freely evaporate.

Additional Information

For additional information on acrylonitrile and its hazards, see the LCSS for acrylonitrile (appended to this SOP).

LCSS for ACRYLONITRILE

LABORATORY CHEMICAL SAFETY SUMMARY: ACRYLONITRILE

Substance	Acrylonitrile	
	(Vinyl cyanide, 2-propenenitrile, cyanoethylene, ACN)	
	CAS 107-13-1	
Formula	$H_2C = CH\text{-}CN$	
Physical Properties	Colorless liquid	
	bp 77 °C, mp -82 °C	
	Moderately soluble in water (7.3 g/100 mL)	
Odor	Mild pyridine-like odor at 2 to 22 ppm	
Vapor Density	1.83 (air = 1.0)	
Vapor Pressure	100 mmHg at 22.8 °C	
Flash Point	-1 °C	
Autoignition Temperature	481 °C	
Toxicity Data	LD_{50} oral (rat)	78 mg/kg
	LD_{50} skin (rabbit)	250 mg/kg
	LC_{50} inhal (rat)	425 ppm (4 h)
	PEL (OSHA)	2 ppm
	TLV-TWA (ACGIH)	2 ppm—skin
Major Hazards	Probable human carcinogen (OSHA "select carcinogen"); moderate acute toxicity; highly flammable.	
Hazard Class(es)	Highly flammable, toxic, potentially explosive, carcinogen	
Toxicity	Acrylonitrile is classified as moderately toxic by acute exposure through oral intake, skin contact, and inhalation. Symptoms of exposure include weakness, lightheadedness, diarrhea, nausea, and vomiting. Acrylonitrile is severely irritating to the eyes and mildly irritating to the skin; prolonged contact with the skin can lead to burns.	

Acrylonitrile is mutagenic in bacterial and mammalian cell cultures and embryotoxic/ teratogenic in rats at levels that produce maternal toxicity. Acrylonitrile is carcinogenic in rats and is regulated by OSHA as a carcinogen (29 CFR 1910.1045). Acrylonitrile is listed in IARC Group 2A ("probable human carcinogen") and is classified as a "select carcinogen" under the criteria of the OSHA Laboratory Standard.

Flammability and Explosibility Highly flammable liquid (NFPA rating = 3). Vapor forms explosive mixtures with air at concentrations of 3 to 17% (by volume). Hazardous gases produced in fire include hydrogen cyanide, carbon monoxide, and oxides of nitrogen. Carbon dioxide or dry chemical extinguishers should be used to fight acrylonitrile fires.

Reactivity and Incompatibility Violent reaction may occur on exposure to strong acids and bases, amines, strong oxidants, copper, and bromine. Violent polymerization can be initiated by heat, light, strong bases, peroxides, and azo compounds.

Storage and Handling […] work with acrylonitrile should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Acrylonitrile should be used only in areas free of ignition sources. Containers of acrylonitrile should be stored in secondary containers in the dark in areas separate from oxidizers and bases.

Accidents In the event of skin contact, immediately wash with soap and water and remove contaminated clothing. In case of eye contact, promptly wash with copious amounts of water for 15 min (lifting upper and lower lids occasionally) and obtain medical attention. If acrylonitrile is ingested, obtain medical attention immediately. If large amounts of this compound are inhaled, move the person to fresh air and seek medical attention at once.

In the event of a spill, remove all ignition sources, soak up the acrylonitrile with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Evacuation and cleanup using respiratory protection may be necessary in the event of a large spill or release in a confined area.

Documentation of Training – SOP Use of Acrylonitrile

(signature of all users is required)

- Prior to conducting any work with acrylonitrile, you must have received training specific to the hazards involved in working with this substance.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

SOP: Use of Benzene

NOTE: Benzene (aka Benzol, PhH) is classified as a Particularly Hazardous Substance (PHS) per Cal-OSHA, since it is listed as a **“Select” Carcinogen**.

Date of last revision to SOP: Mar. 2023 – Kai Ewert

Scope of SOP

Use of benzene in chemistry procedures in the lab

Compound information

Benzene (aka Benzol, PhH) is a mutagen and an OHSA regulated carcinogen. It is a colorless, flammable organic solvent with a sweet smell.

Benzene may be harmful if inhaled; causes respiratory tract irritation; may be harmful if absorbed through skin; causes skin and eye irritation; may be harmful if swallowed. Benzene is an aspiration hazard if swallowed – it can enter lungs and cause damage.

See also the EH&S Fact Sheet on Benzene in Appendix A.

Approval Required

Anyone working for the first time with benzene in this laboratory must consult with Dr. Kai Ewert. Users must study the relevant safety information and be aware of the appropriate waste disposal method (via non-halogenated solvent waste).

General precautions

Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor or mist. Keep away from sources of ignition. Take measures to prevent the buildup of electrostatic charge. Wash hands before breaks and immediately after handling benzene.

Personal Protective Equipment

Users of benzene shall employ the following:

- **Protective eyewear**

ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. For procedures with splash potential, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

Use of a flame-resistant ("blue") lab coat is mandatory, as are long pants or equivalent and closed-toe shoes.

- **Lab gloves**

Standard latex or nitrile gloves do not provide adequate protection from benzene spills. As per UCSB EH&S, only Viton, Polyvinyl Alcohol, or "Barrier" gloves offer protection. Note that Polyvinyl Alcohol is a water soluble polymer, so use caution when also handling aqueous solutions. A small stock of "Barrier" type gloves is usually at hand in the cabinet in room 1032; these gloves are also available from the Physics storeroom.

Engineering/Ventilation Controls

Benzene must be handled in a **fume hood**. Use on the open bench is prohibited.

When outside of the fume hood, containers must be sealed. The use of benzene on an open lab bench, in open containers, will likely result in worker exposures above the Cal-OSHA legal/safe limits for benzene.

Handling, Storage, Cleanup, First Aid, and Disposal Requirements

- **Handling:**

Work with benzene must be performed in the laboratory fume hoods.

- **Storage:**

Benzene must be stored in completely-sealed containers in one of the "Flammables" storage cabinets underneath the fume hoods.

- **Spills/Cleanup:**

Spills of benzene must be cleaned up as rapidly and completely as feasible.
Assess the extent of danger. Help contaminated or injured persons. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
Place leaking containers in a fume hood. If it can be done safely, clean up small spills with absorbent material (e.g. paper towels) and collect all contaminated materials (including gloves) in a tight-closing container. Make sure to wear "Barrier" type gloves if cleaning up a benzene spill. A small stock of "Barrier" type gloves is usually at hand in the cabinet in room 1032; these gloves are also available from the Physics storeroom. For larger spills that can not be safely and completely handled by lab personnel, leave the area and contact EH&S at x3194.

Follow the procedures for emergencies outlined in the beginning of the CHP and in the SOP for chemical spills.

- **First Aid:**

Call 9-911 (from campus phones, else 911) for immediate medical attention.

If inhaled
Move person into fresh air. If not breathing, give artificial respiration and call emergency services. Seek medical attention if needed.
In case of skin contact
Take off contaminated clothing and shoes immediately. Minor skin contact requires washing with soap and water. Soaking or flushing contaminated areas of the skin with water for periods up to 15 minutes is required if a large area comes into contact with benzene, or if prolonged contact occurs. Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician.
In case of eye contact
Check for and remove any contact lenses. Rinse thoroughly with plenty of water for at least 15 minutes (lifting upper and lower lids occasionally). Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician. Continue rinsing eyes during transport to hospital.
If swallowed
Give milk or water to induce vomiting if conscious. Never give anything by mouth to an unconscious person. Rinse mouth with water. Get medical attention immediately.

- **Disposal:**

All benzene wastes must be disposed of through EH&S as non-halogenated solvent waste. No benzene must go into the sewer system, trash or be allowed to freely evaporate.

Additional Information

For additional information on benzene and its hazards, see the LCSS for benzene (appended to this SOP).

LCSS for BENZENE

Substance	Benzene (Benzol) CAS 71-43-2	
Formula	C_6H_6	
Physical Properties	Colorless liquid bp 80.1 °C, mp 5.5 °C Slightly soluble in water (0.18 g/100 mL)	
Odor	"Paint-thinner-like" odor detectable at 12 ppm	
Vapor Density	2.7 (air = 1.0)	
Vapor Pressure	75 mmHg at 20 °C	
Flash Point	-11.1 °C	
Autoignition Temperature	560 °C	
Toxicity Data	LD_{50} oral (rat)	930 mg/kg
	LC_{50} inhal (rat)	10,000 ppm (7 h)
	PEL (OSHA)	1 ppm (3.2 mg/m^3)
	TLV-TWA (ACGIH)	10 ppm (32 mg/m^3)
	STEL (ACGIH)	5 ppm (16 mg/m^3)
Major Hazards	Highly flammable; chronic toxin affecting the blood-forming organs; OSHA "select carcinogen."	
Toxicity	The acute toxicity of benzene is low. Inhalation of benzene can cause dizziness, euphoria, giddiness, headache, nausea, drowsiness, and weakness. Benzene can cause moderate irritation to skin and severe irritation to eyes and mucous membranes. Benzene readily penetrates the skin to cause the same toxic effects as inhalation or ingestion. The chronic toxicity of benzene is significant. Exposure to benzene affects the blood and blood-forming organs such as the bone marrow, causing irreversible injury; blood disorders including anemia and leukemia may result. The symptoms of chronic benzene exposure may include fatigue, nervousness, irritability, blurred vision, and labored breathing. Benzene is regulated by OSHA as a carcinogen (Standard 1910.1028) and is listed in IARC Group 1 ("carcinogenic to humans"). This substance is classified as a "select carcinogen" under the criteria of the OSHA Laboratory Standard.	

Flammability and Explosibility

Benzene is a highly flammable liquid (NFPA rating = 3), and its vapors may travel a considerable distance to a source of ignition and "flash back." Vapor-air mixtures are explosive above the flash point. Carbon dioxide and dry chemical extinguishers should be used to fight benzene fires.

Reactivity and Incompatibility

Fire and explosion hazard with strong oxidizers such as chlorine, oxygen, and bromine (in the presence of certain catalysts such as iron) and with strong acids.

Accidents

In the event of skin contact, immediately wash with soap and water and remove contaminated clothing. In case of eye contact, promptly wash with copious amounts of water for 15 min (lifting upper and lower lids occasionally) and obtain medical attention. If benzene is ingested, obtain medical attention immediately. If large amounts of this compound are inhaled, move the person to fresh air and seek medical attention at once.

In the event of a spill, remove all ignition sources, soak up the benzene with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection should be employed during spill cleanup.

Documentation of Training – SOP Use of Benzene

(signature of all users is required)

- Prior to conducting any work with benzene, you must have received training specific to the hazards involved in working with this substance.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

SOP: Use of Chloroform

Date of last revision to SOP: Mar. 2023 – Kai Ewert

Scope of SOP

Use of chloroform (aka trichloromethane, TCM, $CHCl_3$) in the preparation of lipid and liposome solutions

Compound information

See the appended LCSS for more information. See also the EH&S Fact Sheet on Chlorinated Solvents in Appendix A.

Approval and Training Required

Before using chloroform, users must read the corresponding LCSS which is appended to this SOP.
For graduate student, postdocs and visiting researchers, specific approval is not required before performing this type of work. Undergraduate students and interns should be supervised when performing this work until they have demonstrated proficiency in safely handling hazardous solvents.

Chemical Hazard

Chemical Name	Hazard Class
Chloroform	Toxic (see LCSS for details)

General precautions

Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor or mist. Wash hands before breaks and immediately after handling chloroform.

Personal Protective Equipment

Users handling chloroform must employ the following personal protective measures:

- **Protective eyewear**

ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. For procedures with splash potential, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

Use of a flame-resistant ("blue") lab coat is preferred. Long pants or equivalent as well as closed-toe shoes are mandatory.

- **Lab gloves**

It is important to note that the standard disposable exam gloves provided in the lab (latex or nitrile) do not form an appreciable barrier to chloroform. Even doubling up of these gloves will only provide protection for less than a second, but probably enough to reduce skin exposure if the gloves are removed immediately after exposure. While up to user discretion, the use of thicker and more resistant gloves may not reduce the overall risk of exposure due to the concomitant reduction in dexterity.

Engineering/Ventilation Controls

Chloroform and solvent mixtures containing chloroform must be handled in a **fume hood**. Use on the open bench is prohibited.

When solutions containing chloroform are removed from the fume hood, containers must be sealed. The use of chloroform on an open lab bench, in open containers, will likely result in worker exposures above the Cal-OSHA legal/safe limits for chloroform.

Special Chemical Handling, Storage, Cleanup and Disposal Requirements

- **Storage:**

Chloroform must be stored in completely-sealed containers in one of the chemical storage cabinets underneath the fume hoods that are designated for solvent storage, away from strong bases in particular. For further information on incompatibilities, see the LCSS below.

- **Spills/Cleanup:**

Spills of chloroform must be cleaned up as rapidly and completely as possible.
Assess the extent of danger. Help contaminated or injured persons. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
Place leaking containers in a fume hood. If it can be done safely, clean up small spills with absorbent material (e.g. paper towels), collect all contaminated materials (including gloves) in a tight-closing container, and arrange pickup with EH&S. Make sure to wear "Barrier" type gloves if cleaning up a chloroform spill.

A small stock of "Barrier" type gloves is usually at hand in the cabinet in room 1032; these gloves are also available from the Physics storeroom. Respiratory protection may be necessary in the event of a large spill or in a confined area. Thus, for larger spills that can not be safely and completely handled by lab personnel, e.g. if a high hazard of exposure to fumes is present, leave the area and contact EH&S at x3194. Follow the procedures for emergencies outlined in the beginning of the CHP and in the SOP for chemical spills.

- **First Aid:**

Call 9-911 (from campus phones, else 911) for immediate medical attention.

If inhaled
Move person into fresh air. If not breathing, give artificial respiration and call emergency services. Seek medical attention if needed.
In case of skin contact
Take off contaminated gloves, clothing, and/or shoes immediately. Wash the affected area with soap and copious amounts of water. Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician.
In case of eye contact
Check for and remove any contact lenses. Rinse thoroughly with plenty of water for at least 15 minutes (lifting upper and lower lids occasionally). Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician.
If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Get medical attention immediately.

- **Disposal:**

All chloroform wastes must be disposed of through EH&S like other chemical waste. Chloroform and chloroform-containing solutions should be disposed of by adding them to the "HALOGENATED SOLVENTS" collection bottle and entering the amount added on the list provided. Chloroform must not be allowed to enter the sewer system or trash or be left to freely evaporate.

Additional Information

For additional information on chloroform and its hazards, see its LCSS (appended to this SOP).

LCSS for CHLOROFORM

Substance

Chloroform
(Trichloromethane)
CAS 67-66-3

Formula

$CHCl_3$

Physical Properties

Colorless liquid
bp 61 °C, mp -63.5 °C
Slightly soluble in water (0.8 g/100 mL)

Odor

Ethereal, sweet odor detectable at 133 to 276 ppm (mean = 192 ppm)

Vapor Density

4.1 (air = 1.0)

Vapor Pressure

160 mmHg at 20 °C

Flash Point

Noncombustible

Toxicity Data

LD_{50} oral (rat) 908 mg/kg
LD_{50} skin (rabbit) >20 g/kg
LC_{50} inhal (rat) 9937 ppm (47,702 mg/m^3; 4 h)
PEL (OSHA) 50 ppm (240 mg/m^3; ceiling)
TLV-TWA (ACGIH) 10 ppm (48 mg/m^3)

Major Hazards

Low acute toxicity; skin and eye irritant.

Toxicity

The acute toxicity of chloroform is low by all routes of exposure. Inhalation can cause dizziness, headache, drowsiness, and nausea, and at higher concentrations, disorientation, delirium, and unconsciousness. Inhalation of high concentrations may also cause liver and kidney damage. Exposure to 25,000 ppm for 5 min can be fatal to humans. Ingestion of chloroform can cause severe burning of the mouth and throat, chest pain, and vomiting. Chloroform is irritating to the skin and eyes, and liquid splashed in the eyes can cause burning pain and reversible corneal injury. Olfactory fatigue occurs on exposure to chloroform vapor, and it is not regarded as a substance with adequate warning properties.

Chloroform shows carcinogenic effects in animal studies and is listed by IARC in Group 2B ("possible human carcinogen"). It is not classified as a "select carcinogen" according to the criteria of the OSHA Laboratory Standard. Prolonged or repeated exposure to this substance may result in liver and kidney injury. There is some evidence from animal studies that chloroform is a developmental and reproductive toxin.

Flammability and Explosibility

Chloroform is noncombustible. Exposure to fire or high temperatures may lead to formation of phosgene, a highly toxic gas.

Reactivity and Incompatibility

Chloroform reacts violently with alkali metals such as sodium and potassium, with a mixture of acetone and base, and with a number of strong bases such as potassium and sodium hydroxide, potassium *t*-butoxide, sodium methoxide, and sodium hydride. Chloroform reacts explosively with fluorine and dinitrogen tetroxide.

Storage and Handling

Chloroform should be handled in the laboratory using the "basic prudent practices" described in Chapter 5.C. In the presence of light, chloroform undergoes autoxidation to generate phosgene; this can be minimized by storing this substance in the dark under nitrogen. Commercial samples of chloroform frequently contain 0.5 to 1% ethanol as a stabilizer.

Accidents

In the event of skin contact, immediately wash with soap and water and remove contaminated clothing. In case of eye contact, promptly wash with copious amounts of water for 15 min (lifting upper and lower lids occasionally) and obtain medical attention.

If chloroform is ingested, obtain medical attention immediately. If large amounts of this compound are inhaled, move the person to fresh air and seek medical attention at once.

In the event of a spill, soak up chloroform with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area.

The information in this LCSS has been compiled by a committee of the National Research Council from literature sources and Material Safety Data Sheets. This summary is intended for use by trained laboratory personnel in conjunction with the NRC report *Prudent Practices in the Laboratory*. This LCSS presents a concise summary of safety information that should be adequate for most laboratory uses of the title substance, but in some cases it may be advisable to consult more comprehensive references. This information should not be used as a guide to the nonlaboratory use of this chemical.

Documentation of Training – SOP Use of Chloroform

(signature of all users is required)

- Prior to conducting any work with chloroform, you must have received training specific to the hazards involved in working with this substance.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

This page intentionally left blank

SOP: Use of Dichloromethane

NOTE: Dichloromethane (aka methylene chloride, CH_2Cl_2, DCM) is classified as a Particularly Hazardous Substance (PHS) per Cal-OSHA, since it is listed as a **“Select” Carcinogen**.

Date of last revision to SOP: Mar. 2023 – Kai Ewert

Scope of SOP

Use of dichloromethane in chemistry procedures in the lab

Compound information

See also the EH&S Fact Sheets on chlorinated solvents and on dichloromethane in Appendix A.

Dichloromethane (aka methylene chloride, CH_2Cl_2, DCM) is an OHSA regulated carcinogen. It is a colorless organic solvent.

Dichloromethane is very hazardous in case of eye contact (irritant), of ingestion, and of inhalation. Inflammation of the eye is characterized by redness, watering, and itching. Eye contact may cause temporal eye damage. In case of ingestion, DCM may cause irritation of the gastrointestinal tract with vomiting. If vomiting results in aspiration, chemical pneumonia could follow. Absorption through gastrointestinal tract may produce symptoms of central nervous system depression ranging from light headedness to unconsciousness.

Dichloromethane is hazardous in case of skin contact (irritant, permeator). Chronic exposure to dichloromethane can cause headache, mental confusion, depression, liver effects, kidney effects, bronchitis, loss of appetite, nausea, lack of balance, and visual disturbances. Dichloromethane can cause dermatitis upon prolonged skin contact. Dichloromethane may cause cancer in humans.

Approval Required

Anyone working for the first time with dichloromethane in this laboratory must consult with Dr. Kai Ewert. Users must study the relevant safety information and be aware of the appropriate waste disposal method (via halogenated solvent waste).

General precautions

Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor or mist. Wash hands before breaks and immediately after handling dichloromethane.

Personal Protective Equipment

Users of dichloromethane shall employ the following:

- **Protective eyewear**

ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. For procedures with splash potential, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

Use of a flame-resistant ("blue") lab coat is mandatory, as are long pants and closed-toe shoes.

- **Lab gloves**

Standard latex or nitrile gloves do not provide adequate protection from dichloromethane spills. As per UCSB EH&S, only "Silver Shield", Viton, Polyvinyl Alcohol, or "Barrier" gloves offer protection. Note that Polyvinyl Alcohol is a water soluble polymer, so use caution when also handling aqueous solutions. A small stock of "Barrier" type gloves is usually at hand in the cabinet in room 1032; these gloves are also available from the Physics storeroom.

Engineering/Ventilation Controls

Dichloromethane must be handled in a **fume hood**. Use on the open bench is prohibited.

When outside of the fume hood, containers must be sealed. The use of dichloromethane on an open lab bench, in open containers, will likely result in worker exposures above the Cal-OSHA legal/safe limits for dichloromethane.

Handling, Storage, Cleanup, First Aid, and Disposal Requirements

- **Handling:**

Work with dichloromethane must be performed in the laboratory fume hoods.

- **Storage:**

Dichloromethane must be stored in completely sealed containers in one of the storage cabinets underneath the fume hoods.

- **Spills/Cleanup:**

Spills of dichloromethane must be cleaned up as rapidly and completely as possible.
Assess the extent of danger. Help contaminated or injured persons. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area

using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
Place leaking containers in a fume hood. If it can be done safely, clean up small spills with absorbent material (e.g. paper towels) and collect all contaminated materials (including gloves) in a tight-closing container. Make sure to wear “Barrier” type gloves if cleaning up a dichloromethane spill. A small stock of “Barrier” type gloves is usually at hand in the cabinet in room 1032; these gloves are also available from the Physics storeroom. For larger spills that can not be safely and completely handled by lab personnel, leave the area and contact EH&S at x3194. Follow the procedures for emergencies outlined in the beginning of the CHP and in the SOP for chemical spills.

- **First Aid:**

Call 9-911 (from campus phones, else 911) for immediate medical attention.

If inhaled
Move person into fresh air. If not breathing, give artificial respiration and call emergency services. Seek medical attention if needed.
In case of skin contact
Take off contaminated clothing and shoes immediately. Minor skin contact requires washing with soap and water. Soaking or flushing contaminated areas of the skin with water for periods up to 15 minutes is required if a large area comes into contact with dichloromethane, or if prolonged contact occurs. Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician.
In case of eye contact
Check for and remove any contact lenses. Rinse thoroughly with plenty of water for at least 15 minutes (lifting upper and lower lids occasionally). Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician. Continue rinsing eyes during transport to hospital.
If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Get medical attention immediately.

- **Disposal:**

All dichloromethane wastes must be disposed of through EH&S as halogenated solvent waste. No dichloromethane must go into the sewer system, trash or be allowed to freely evaporate.

Additional Information

For additional information on dichloromethane and its hazards, see the LCSS for dichloromethane (appended to this SOP).

LCSS for DICHLOROMETHANE

Substance	Dichloromethane (Methylene chloride; aerothene MM) CAS 75-09-2	
Formula	CH_2Cl_2	
Physical Properties	Colorless liquid bp 40 °C, mp -97 °C Slightly soluble in water (1.32 g/100 mL)	
Odor	Odor threshold 160 to 230 ppm	
Vapor Density	2.93 (air = 1.0)	
Vapor Pressure	440 mmHg at 25 °C	
Flash Point	Noncombustible	
Autoignition Temperature	556 °C	
Toxicity Data	LD_{50} oral (rat)	1600 mg/kg
	LC_{50} inhal (rat)	88,000 mg/m^3; 30 min
	PEL (OSHA)	500 ppm (8 h)
	TLV-TWA (ACGIH)	50 ppm

Major Hazards Low acute toxicity; skin and eye irritant.

Toxicity Dichloromethane is classified as only slightly toxic by the oral and inhalation routes. Exposure to high concentrations of dichloromethane vapor (>500 ppm for 8 h) can lead to lightheadedness, fatigue, weakness, and nausea. Contact of the compound with the eyes causes painful irritation and can lead to conjunctivitis and corneal injury if not promptly removed by washing. Dichloromethane is a mild skin irritant, and upon prolonged contact (e.g., under the cover of clothing or shoes) can cause burns after 30 to 60 min exposure.
Dichloromethane is not teratogenic at levels up to 4500 ppm or embryotoxic in rats and mice at levels up to 1250 ppm.

Flammability and Explosibility Noncombustible. Dichloromethane vapor concentrated in a confined or poorly ventilated area can be ignited with a high-energy spark, flame, or high-intensity heat source.

Reactivity and Incompatibility Reacts violently with alkali metals, aluminum, magnesium powder, potassium *t*-butoxide, nitrogen tetroxide, and strong oxidizing agents.

Accidents In the event of skin contact, immediately wash with soap and water and remove contaminated clothing. In case of eye contact, promptly wash with copious amounts of water for 15 min (lifting upper and lower lids occasionally) and obtain medical attention. If dichloromethane is ingested, obtain medical attention immediately.

If large amounts of this compound are inhaled, move the person to fresh air and seek medical attention at once.

In the event of a spill, soak up dichloromethane with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area.

Documentation of Training – SOP Use of Dichloromethane

(signature of all users is required)

- Prior to conducting any work with dichloromethane, you must have received training specific to the hazards involved in working with this substance.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

SOP: Use of Ethidium Bromide

Date of last revision to SOP: Aug. 2014 – Kai Ewert

Scope of SOP

Use of ethidium bromide for the detection and approximate quantification of nucleic acids by fluorescence

Compound information

Ethidium bromide (EtBr) is a mutagen. If not stored and handled properly, this can pose a serious threat to the health and safety of laboratory personnel, emergency responders and chemical waste handlers. Hence, it is important to follow safe protocols for handling and disposal.

EtBr can be absorbed through skin, and will stain it purple. EtBr is an irritant to the skin, eyes, mouth, and upper respiratory tract.

Ethidium Bromide is commonly used as a non-radioactive DNA stain to identify and visualize nucleic acid bands in electrophoresis and perform other methods of nucleic acid separation. Solutions of EtBr fluoresce readily with a reddish-brown color when exposed to ultraviolet (UV) light.

Approval and Training Required

Before using ethidium bromide, users must read the corresponding LCSS which is appended to this SOP.

For graduate student, postdocs and visiting researchers, specific approval is not required before performing this type of work. Undergraduate students and interns should be supervised when performing this work until they have demonstrated proficiency in safely handling the hazardous materials involved.

Chemical Hazard

Chemical Name	Hazard
Ethidium Bromide	Highly mutagenic (see LCSS for details)

General precautions

Avoid contact with skin, eyes and clothing. Avoid inhalation of dust or mist/aerosols from solutions. Wash hands before breaks and immediately after handling ethidium bromide and its solutions.

Personal Protective Equipment

Users handling ethidium bromide must use the following personal protective equipment:

NOTE: Use UV light to check reusable protective equipment (e.g. safety glasses, lab coats) for contamination with ethidium bromide.

- **Protective eyewear**

  ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. For procedures with splash potential, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

  Use a lab coat (appropriate for the lab and work being performed as per LHAT) is mandatory, as are long pants and closed-toe shoes.

- **Lab gloves**

  To protect the skin from exposure to ethidium bromide powder and aqueous solutions, nitrile or latex disposable exam gloves must be worn. Inspect gloves prior to use. Do not reuse gloves used for working with ethidium bromide.

Users handling ethidium bromide are encouraged to employ the following personal protective measures:

Engineering/Ventilation Controls

While the use of a fume hood is not required for work involving aqueous solutions of ethidium bromide, care must be taken to minimize dispersion of the powder form of ethidium bromide into the lab air.

Means should be taken to facilitate the cleanup of potential spills. This includes covering of lab benches with adsorbent but impermeable covering (available in the lab) and / or handling of ethidium bromide and its solutions in a fume hood.

Special Chemical Handling, Storage, Cleanup and Disposal Requirements

- **Storage:**

There are no special storage requirements for ethidium bromide. However, any containers with ethidium bromide must be clearly labeled as “highly toxic”.

- **First Aid:**

Call 9-911 (from campus phones, else 911) for immediate medical attention.

If inhaled
If EtBr dust is inhaled, move the victim to a source of fresh air. Seek medical attention immediately.
In case of skin contact
Take off contaminated clothing and shoes immediately. Wash the affected area with soap and copious amounts of water for 15 minutes. Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician.
In case of eye contact
Check for and remove any contact lenses. Rinse thoroughly with plenty of water for at least 15 minutes (lifting upper and lower lids occasionally). Use the lab emergency shower/eyewash or a faucet as appropriate.
If swallowed
In the case of EtBr ingestion, obtain medical attention immediately.

- **Spills/Cleanup:**

Spills of ethidium bromide must be cleaned up as rapidly and completely as possible.
Assess the extent of danger. Help contaminated or injured persons. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
Avoid raising dust when cleaning up a powder spill, e.g. by covering the spill with a layer of moistened paper towels. If it can be done safely, clean up small spills (after putting on two layers of disposable nitrile gloves) with absorbent material (e.g. paper towels). Collect all contaminated materials (including gloves) in a tight-closing container, and arrange pickup with EH&S. Check for successful decontamination with UV light.
For larger spills that can not be safely and completely handled by lab personnel, leave the area and contact EH&S at x3194. Follow the procedures for emergencies outlined in the beginning of the CHP and in the SOP for chemical spills.

- **Disposal:**

All ethidium bromide wastes must be disposed of through EH&S like other chemical waste. Ethidium bromide wastes require their own, separate collection container. If no such container is available in the lab’s chemical waste storage area, start a new container (contact Kai Ewert with questions on how to do this)

Additional Information

For additional information on ethidium bromide and its hazards, see its LCSS (appended to this SOP) and the EH&S fact sheet on ethidium bromide safety in Appendix A.

LCSS for ETHIDIUM BROMIDE

Substance

Ethidium bromide
(Dromilac, homidium bromide)
CAS 1239-45-8

Formula

$C_{21}H_{20}BrN_3$

Physical Properties

Dark red crystals
mp 260 to 262 °C
Soluble in water (5 g/100 mL)

Odor

Odorless solid

Major Hazards

Potent mutagen

Toxicity

Acute toxic effects from exposure to ethidium bromide have not been thoroughly investigated. Ethidium bromide is irritating to the eyes, skin, mucous membranes, and upper respiratory tract.

Although there is no evidence for the carcinogenicity or teratogenicity of this substance in humans, ethidium bromide is strongly mutagenic and therefore should be regarded as a possible carcinogen and reproductive toxin.

Flammability and Explosibility

Ethidium bromide does not pose a flammability hazard (NFPA rating = 1).

Reactivity and Incompatibility

No incompatibilities are known.

Storage and Handling

Ethidium bromide should be handled in the laboratory using the "basic prudent practices" described in Chapter 5.C. Because of its mutagenicity, stock solutions of this compound should be prepared in a fume hood, and protective gloves should be worn at all times while handling this substance. Operations capable of generating ethidium bromide dust or aerosols of ethidium bromide solutions should be conducted in a fume hood to prevent exposure by inhalation.

Accidents

In the event of skin contact, immediately wash with soap and water and remove contaminated clothing. In case of eye contact, promptly wash with copious amounts of water for 15 min (lifting upper and lower lids occasionally) and obtain medical attention. If ethidium bromide is ingested, obtain medical attention immediately.

In the event of a spill, mix ethidium bromide with an absorbent material (avoid raising dust), place in an appropriate container, and dispose of properly. Soak up aqueous solutions with a spill pillow or absorbent material.

Disposal

Excess ethidium bromide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your institution's waste disposal guidelines.

The information in this LCSS has been compiled by a committee of the National Research Council from literature sources and Material Safety Data Sheets. This summary is intended for use by trained laboratory personnel in conjunction with the NRC report *Prudent Practices in the Laboratory*. This LCSS presents a concise summary of safety information that should be adequate for most laboratory uses of the title substance, but in some cases it may be advisable to consult more comprehensive references. This information should not be used as a guide to the nonlaboratory use of this chemical.

Documentation of Training – SOP Use of Ethidium Bromide

(signature of all users is required)

- Prior to conducting any work with ethidium bromide, you must have received training specific to the hazards involved in working with this substance.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

SOP: Use of Formaldehyde and Formalin (aqueous formaldehyde solution)

NOTE: Formaldehyde is classified as a Particularly Hazardous Substance (PHS) per Cal-OSHA, since it is listed as a **"Select" Carcinogen**.

Date of last revision to SOP: Mar. 2023 – Kai Ewert

NOTE: For brevity, in the following "formaldehyde" refers to formaldehyde as well as its aqueous solutions ("formalin"), unless otherwise specified.

Compound information

Formaldehyde an OHSA regulated carcinogen. Formaldehyde is a flammable gas at room temperature that is mainly used in laboratories and sold as a solution in water or methanol. It is commonly used as a fixative and as a nucleic acid denaturant. The odor threshold of formaldehyde is reported to be as low as 0.1 ppm. The OSHA Permissible Exposure Limit is 0.75 ppm in an eight hour time weighted average.

Formaldehyde is hazardous in case of eye contact (irritant) and of ingestion; slightly hazardous in case of skin contact (irritant, sensitizer, permeator); Non-corrosive for skin, eyes, or lungs. Chronic skin contact is slightly hazardous (sensitizer). Severe over-exposure can result in death.

Formaldehyde is mutagenic for mammalian somatic cells and for bacteria and/or yeast. It is classified as a possible teratogen for humans and as a reproductive system toxin. Formaldehyde may be toxic to kidneys, liver, central nervous system (CNS). Repeated or prolonged exposure can produce target organs damage. Repeated exposure to a highly toxic material may produce general deterioration of health by an accumulation in one or many human organs.

Approval Required

Anyone working for the first time with formaldehyde in this laboratory needs to consult with Dr. Kai Ewert. Users must study the relevant safety information and ensure an appropriate waste disposal method is in place before commencing work.

General precautions

Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor or mist. Wash hands before breaks and immediately after handling formaldehyde.

Personal Protective Equipment

Users of formaldehyde shall employ the following:

- **Protective eyewear**

ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. Formaldehyde poses a severe threat of injury to the eye. Accordingly, for procedures with splash potential, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

Use of an appropriate lab coat for the work and areas you work in (as per LHAT) is mandatory, as are long pants or equivalent and closed-toe shoes.

- **Lab gloves**

Gloves must be worn when handling formaldehyde. Nitrile and neoprene gloves are the **only** acceptable choices as per EH&S.

Engineering/Ventilation Controls

Formaldehyde must be handled in a **fume hood or the biosafety cabinet**. Use on the open bench is prohibited except when it is impractical (i.e. equipment will not fit in hood), in which case you need to check with Kai Ewert before performing the work.

When used outside of the above containment devices, containers must be sealed. The use of formaldehyde on an open lab bench, in open containers, will likely result in worker exposures above the Cal-OSHA legal/safe limits for formaldehyde.

Handling, Storage, Cleanup, First Aid, and Disposal Requirements

- **Handling:**

Work with formaldehyde must be performed in the laboratory fume hoods or the biosafety cabinet, or in a closed container.

- **Storage:**

Unless in current use, formaldehyde must be stored in completely sealed containers in one of the chemical storage cabinets underneath the fume hoods.

- **Spills/Cleanup:**

Spills of formaldehyde must be cleaned up as quickly and completely as possible.
Assess the extent of danger. Help contaminated or injured persons. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
Place leaking containers in a fume hood. If it can be done safely, clean up small spills with absorbent material (e.g. paper towels) and collect all contaminated materials (including gloves) in a tight-closing container. Wear doubled nitrile

gloves. For larger spills that can not be safely and completely handled by lab personnel, leave the area and contact EH&S at x3194. Follow the procedures for emergencies outlined in the beginning of the CHP and in the SOP for chemical spills.

- **First Aid:**

Call 9-911 (from campus phones, else 911) for immediate medical attention.

If inhaled
Move person into fresh air. If not breathing, give artificial respiration and call emergency services. If breathing is difficult, give oxygen. Seek medical attention.
In case of skin contact
Take off contaminated clothing and shoes immediately. Flush contaminated areas of the skin with plenty of water for at least 15 minutes. Use the lab emergency shower/eyewash or a faucet as appropriate. Take the victim immediately to a hospital.
In case of eye contact
Check for and remove any contact lenses. Rinse thoroughly with plenty of water for at least 15 minutes (lifting upper and lower lids occasionally). Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician. Continue rinsing eyes during transport to hospital.
If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Get medical attention immediately. If the victim is conscious and alert, give milk, activated charcoal, or water.

- **Disposal:**

All formaldehyde wastes must be disposed of through EH&S like other chemical waste. No formaldehyde must go into the sewer system, trash or be allowed to freely evaporate. If no appropriate / designated collection bottle / procedure is in place, contact Kai Ewert.

Additional Information

For additional information on formaldehyde and its hazards, see the LCSS for formaldehyde (appended to this SOP) and the EH&S Fact Sheet in Appendix A.

LCSS for FORMALDEHYDE

Substance

Formaldehyde
(Methanal; 37% aqueous solution (usually containing 10 to 15% methanol) is called formalin; solid polymer is called paraformaldehyde)
CAS 50-00-0

Formula

HCHO

Physical Properties

Clear, colorless liquid
Formaldehyde: bp -19 °C, mp -92 °C
Formalin: bp 96 °C, mp -15 °C
Miscible with water

Odor

Pungent odor detectable at 1 ppm

Vapor Density

~1 (air = 1.0)

Vapor Pressure

Formaldehyde: 10 mmHg at -88 °C
Formalin: 23 to 26 mmHg at 25 °C

Flash Point

50 °C for formalin containing 15% methanol

Autoignition Temperature

424 °C for formalin containing 15% methanol

Toxicity Data

LD_{50} oral (rat) 500 mg/kg
LD_{50} skin (rabbit) 270 mg/kg
LC_{50} inhal (rat) 203 mg/m^3(2 h)
PEL (OSHA) 1 ppm (1.5 mg/m^3)
TLV-TWA (ACGIH) 0.3 ppm (ceiling)(0.37 mg/m^3)
STEL (OSHA) 2 ppm (2.5 mg/m^3)

Major Hazards

Probable human carcinogen (OSHA "select carcinogen"); moderate acute toxicity; skin sensitizer.

Toxicity

Formaldehyde is moderately toxic by skin contact and inhalation. Exposure to formaldehyde gas can cause irritation of the eyes and respiratory tract, coughing, dry throat, tightening of the chest, headache, a sensation of pressure in the head, and palpitations of the heart. Exposure to 0.1 to 5 ppm causes irritation of the eyes, nose, and throat; above 10 ppm severe lacrimation occurs, burning in the nose and throat is experienced, and breathing becomes difficult. Acute exposure to concentrations above 25 ppm can cause serious injury, including fatal pulmonary edema. Formaldehyde has low acute toxicity via the oral route. Ingestion can cause irritation of the mouth, throat, and stomach, nausea, vomiting, convulsions, and coma. An oral dose of 30 to 100 mL of 37% formalin can be fatal in humans. Formalin solutions can cause severe eye burns and loss of vision. Eye contact may lead to delayed effects that are not appreciably eased by eye washing.

Formaldehyde is regulated by OSHA as a carcinogen (Standard 1910.1048) and is listed in IARC Group 2A ("probable human carcinogen"). This substance is classified as a "select carcinogen" under the criteria of the OSHA Laboratory Standard. Prolonged or repeated exposure to formaldehyde can cause dermatitis and sensitization of the skin and respiratory tract. Following skin contact, a symptom-free period may occur in sensitized individuals. Subsequent exposures can then lead to itching, redness, and the formation of blisters.

Flammability and Explosibility

Formaldehyde gas is extremely flammable; formalin solution is a combustible liquid (NFPA rating = 2 for 37% formaldehyde (15% methanol), NFPA rating = 4 for 37% formaldehyde (methanol free)). Toxic vapors may be given off in a fire. Carbon dioxide or dry chemical extinguishers should be used to fight formaldehyde fires.

Reactivity and Incompatibility

Formaldehyde may react violently with strong oxidizing agents, ammonia and strong alkalis, isocyanates, peracids, anhydrides, and inorganic acids. Formaldehyde reacts with HCl to form the potent carcinogen, bis-chloromethyl ether.

Storage and Handling

[…] work with formaldehyde should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Formaldehyde should be used only in areas free of ignition sources. Containers of formaldehyde should be stored in secondary containers in areas separate from oxidizers and bases.

Accidents

In the event of skin contact, immediately wash with soap and water and remove contaminated clothing. In case of eye contact, promptly wash with copious amounts of water for 15 min (lifting upper and lower lids occasionally) and obtain medical attention. If formaldehyde is ingested, obtain medical attention immediately. If large amounts of this compound are inhaled, move the person to fresh air and seek medical attention at once.

In the event of a spill, remove all ignition sources, soak up the formaldehyde with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area.

Documentation of Training – SOP Use of Formaldehyde

(signature of all users is required)

- Prior to conducting any work with formaldehyde, you must have received training specific to the hazards involved in working with this substance.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

This page intentionally left blank

SOP: Use of "Particularly Hazardous Substances"

Date of last revision to SOP: Aug. 2014 (Kai Ewert)

Prepared from a template provided by UCSB EH&S.

Definitions / Compound Lists

Per Cal-OSHA, Particularly Hazardous Substances (PHS) are **"Select" Carcinogens, Reproductive Toxins and Acute Toxins**. Links to definitions and lists of these materials are below.

"Select" Carcinogens

(see list at https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp/sec3/particularly-hazardous-substances)

"Select" Carcinogens include carcinogens which are further regulated by Cal-OSHA, e.g. formaldehyde, acrylonitrile, dichloromethane, benzene, (see the corresponding SOPs), chromium VI compounds (e.g. sodium chromate), cadmium compounds, and arsenic compounds (e.g. cacodylic acid, sodium cacodylate). Laboratory fact sheets on these materials may be available from the EH&S website. A list of laboratory safety fact sheets is available at

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/fact-sheets

Reproductive Toxins

(see list at https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp/sec3/particularly-hazardous-substances)

Acute toxins

(see list at https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp/sec3/particularly-hazardous-substances)

Approval Required

Discuss materials, procedures, and protective measures with Kai Ewert before beginning any work with PHS.

General precautions

Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor, mist or aerosols. Wash hands before breaks and immediately after handling.

Personal Protective Equipment

Use of PHS must employ the following:

- **Protective eyewear**

ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. When handling corrosives in large quantities (e.g. > 1 gallon) or when performing procedures with a high potential for splashes, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

You must use a fire-resistant ("blue") lab coat if working in the main MRL labs (rooms 1012, 1024, 1032). You must also wear long pants or equivalent and closed-toe shoes.

- **Lab gloves**

If you need gloves to prevent skin exposure, make sure to check that the gloves you plan to use are resistant (impermeable) to the material in question. Note that some common carcinogens such as dichloromethane and benzene readily permeate common lab gloves such as latex, nitrile and neoprene. Here are glove guidelines for "select" carcinogens that are stored in the lab but not currently used:

- for protection from chromium VI compounds – use butyl or viton or nitrile gloves
- hand protection from cadmium and arsenic can be achieved by wearing gloves appropriate for the solvent in which these chemicals are dissolved. In the typical case of the solvent being water, nitrile or latex gloves will suffice

A chart of chemical resistance of common laboratory gloves is shown on page 36.

Additional information on the selection of proper gloves can be found at

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp/sec2/selecting-proper-gloves

Engineering/Ventilation Controls

Volatile, or dust/aerosol-producing PHS must be used in a **fume hood or the biosafety cabinet**. Use on the open bench is prohibited.

When used outside of the above containment devices, containers must be sealed. Note that the use of volatile PHS such as formalin, acrylonitrile, dichloromethane and benzene on an open lab bench, in open containers, would probably result in worker exposures above the Cal-OSHA legal/safe limits for such materials.

Special Chemical Handling, Storage, Cleanup or Disposal Requirements

Under the CHP law, an area must be designated for working with PHS. The designated area may be the entire laboratory, an area of the lab, or a device such as a laboratory hood. **At UCSB, the designated PHS work area is the entire laboratory**, unless the supervisor specifies otherwise herein; either in general, or for a specific material or operation.

PHS must be stored in completely-sealed containers. Although hood storage of chemicals is generally discouraged, volatile PHS can be stored in a fume hood if deemed necessary.

Spills of PHS must be completely cleaned up.
Assess the extent of danger. Help contaminated or injured persons. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
Spills that can not be safely and completely handled by lab personnel must be reported to EH&S at x3194 for assistance. Follow the procedures for emergencies outlined in the beginning of the CHP and in the SOP for chemical spills.

Like all chemical wastes, disposal of PHS must be done through EH&S. No PHS, or other chemical wastes can go into the sewer system, trash or be allowed to freely evaporate. If no appropriate / designated collection bottle / procedure is in place, contact Kai Ewert.

This page intentionally left blank

SOP: Use of Hexane(s)

Date of last revision to SOP: Oct. 2016 – Kai Ewert

Scope of SOP

Use of hexane or hexanes (isomer mixture) as a solvent, an eluent for chromatography, and for cleaning

Compound information

n-Hexane is a neurotoxin and therefore must be handled with care and the appropriate safety precautions. See the toxicity information below for more information.

n-Hexane melts at –63.5 °C and boils at 61 °C.

Alternatives to Hexane(s)

The neurotoxicity of *n*-Hexane stands out over that of other alkanes because it is readily metabolized to 2,5-hexanedione. Thus, other simple alkanes can provide a much less toxic alternative. The table below lists three common alternatives and considerations for their use.

Alternative solvent	Drawbacks/considerations
Cyclohexane	High viscosity – significantly slows down/ increases pressure in flash chromatography High melting point (6.5 °C) – may limit use as a reaction medium Somewhat less powerful solvent (e.g. for vacuum grease) – may limit use for cleaning purposes, and as reaction or recrystallization solvent
Pentane	Low boiling point (36 °C) – may affect use as eluent for chromatography in solvent mixtures and other uses Less powerful solvent – limits use for cleaning purposes, and as reaction or recrystallization solvent Higher price
Heptane	Higher boiling point (98 °C) – may affect use as eluent for chromatography in solvent mixtures Higher price

→ CyH as a possible alternative (give drawbacks also though)

→ also pentane, heptane(s) as alternatives w/ drawbacks

safety precautions. See the toxicity information below for more information.

Approval and Training Required

Before using hexane(s), users must read the toxicity information below.
For graduate student, postdocs and visiting researchers, specific approval is not required before performing this type of work. Undergraduate students and interns should be supervised when performing this work until they have demonstrated proficiency in safely handling hazardous solvents.

Chemical Hazard

Chemical Name	Hazard Class
Hexane(s)	Neurotoxic (see below for details)

General precautions

Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor or mist. Wash hands before breaks and immediately after handling hexane(s).

Personal Protective Equipment

Users handling hexane(s) must employ the following personal protective measures:

- **Protective eyewear**

ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. For procedures with splash potential, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

Use of a flame-resistant ("blue") lab coat is required. Long pants or equivalent as well as closed-toe shoes are mandatory.

- **Lab gloves**

Note that while nitrile and neoprene gloves are suitable for work with hexane(s) (see chart on pg. 36), **latex gloves are not**.

Engineering/Ventilation Controls

Hexane(s) and solvent mixtures containing hexane(s) must be handled in a **fume hood**. Use on the open bench is prohibited.

When solutions containing hexane(s) are removed from the fume hood, containers must be sealed. The use of hexane(s) on an open lab bench, in open containers, will likely result in worker exposures above the Cal-OSHA legal/safe limits for hexane(s).

Special Chemical Handling, Storage, Cleanup and Disposal Requirements

- **Storage:**

Hexane(s) must be stored in completely-sealed containers in one of the chemical storage cabinets underneath the fume hoods that are designated for solvent storage.

- **Spills/Cleanup:**

Spills of hexane(s) must be cleaned up as rapidly and completely as possible.
Assess the extent of danger. Help contaminated or injured persons. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
Place leaking containers in a fume hood. If it can be done safely, clean up small spills with absorbent material (e.g. paper towels), collect all contaminated materials (including gloves) in a tight-closing container, and arrange pickup with EH&S. Make sure to wear appropriate gloves (see above) when cleaning up a spill. “Barrier” type gloves are recommended for big spills. ll. A small stock of “Barrier” type gloves is usually at hand in the cabinet in room 1032; these gloves are also available from the Physics storeroom. Respiratory protection may be necessary in the event of a large spill or in a confined area. Thus, for larger spills that can not be safely and completely handled by lab personnel, e.g. if a high hazard of exposure to fumes is present, leave the area and contact EH&S at x3194. Follow the procedures for emergencies outlined in the beginning of the CHP and in the SOP for chemical spills.

- **First Aid:**

Call 9-911 (from campus phones, else 911) for immediate medical attention.

If inhaled
Move person into fresh air. If not breathing, give artificial respiration and call emergency services. Seek medical attention if needed.
In case of skin contact
Take off contaminated gloves, clothing, and/or shoes immediately. Wash the affected area with soap and copious amounts of water. Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician.

In case of eye contact
Check for and remove any contact lenses. Rinse thoroughly with plenty of water for at least 15 minutes (lifting upper and lower lids occasionally). Use the lab emergency shower/eyewash or a faucet as appropriate. Consult a physician.
If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Get medical attention immediately.

- **Disposal:**

All hexane(s) waste must be disposed of through EH&S like other chemical waste. Hexane(s) and solvent mixtures of them (unless containing chloroform or dichloromethane) should be disposed of by adding them to the "NON-HALOGENATED SOLVENTS" collection bottle and entering the amount added on the list provided. Hexane(s) must not be allowed to enter the sewer system or trash or be left to freely evaporate.

Additional Information

For additional information on hexane(s) and its hazards, see below (from https://pubchem.ncbi.nlm.nih.gov/compound/8058).

Substance

n-Hexane
(Hexane)
CAS 110-54-3

Used as a solvent, paint thinner, and chemical reaction medium.

Formula

C_6H_{14} or $CH_3[CH_2]_4CH_3$

Physical Properties

Clear colorless liquid with a petroleum-like odor

bp 61 °C, mp -63.5 °C
Less dense than water and insoluble in water. Vapors heavier than air.

Flash Point

-9 °F

Toxicity

1. Exposure Routes

The substance can be absorbed into the body by inhalation, ingestion, skin and/or eye contact

2. Exposure Symptoms

   Irritation of eyes, nose, skin; nausea, headache; peripheral neuropathy: numb extremities, muscle weak; dermatitis; dizziness, drowsiness. lethargy. headache. nausea. weakness. unconsciousness; chemical pneumonitis (aspiration liquid)

3. Target Organs

   Eyes, skin, respiratory system, heart, central nervous system, peripheral nervous system

4. Acute Effects

   - Acute inhalation exposure of humans to high levels of hexane causes mild CNS depression. CNS effects include dizziness, giddiness, slight nausea, and headache in humans.
   - Acute exposure to hexane vapors may cause dermatitis and irritation of the eyes and throat in humans.
   - Acute animal tests in rats have demonstrated hexane to have low acute toxicity from inhalation and ingestion exposure.

5. Chronic Effects

   - Chronic inhalation exposure to hexane is associated with sensorimotor polyneuropathy in humans, with numbness in the extremities, muscular weakness, blurred vision, headache, and fatigue observed.
   - Rats, chronically exposed by inhalation, have exhibited neurotoxic effects.
   - Mild inflammatory, erosive, and degenerative lesions in the olfactory and respiratory epithelium of the nasal cavity have been observed in mice chronically exposed by inhalation. Pulmonary lesions have also been observed in chronically exposed rabbits.
   - The Reference Concentration (RfC) for hexane is 0.2 milligrams per cubic meter (mg/m3) based on neurotoxicity in humans and epithelial lesions in the nasal cavity in mice. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious noncancer effects during a lifetime. It is not a direct estimator of risk but rather a reference point to gauge the potential effects. At exposures increasingly greater than the RfC, the potential for adverse health effects increases. Lifetime exposure above the RfC does not imply that an adverse health effect would necessarily occur.

- EPA has medium confidence in the epidemiological study on which the RfC was based because the lowest-observed-adverse-effect level (LOAEL) in this study was based on neurotoxicology, and this endpoint is supported by numerous other subchronic inhalation studies in animals and by human occupational studies; medium confidence in the database because of the lack of long-term inhalation studies and appropriate reproductive studies; and, consequently, medium confidence in the RfC.
- EPA has not established a Reference Dose (RfD) for hexane.
- EPA has calculated a provisional RfD of 0.06 milligrams per kilogram body weight per day (mg/kg/d) based on neurological and reproductive effects in rats.

Toxicity Summary

CNS depression, convulsions, coma and death may follow acute exposures to large concentrations. Inhalation of n-hexane usually causes eye, nose, throat and respiratory irritation, which are rapidly reversible when exposure is discontinued. Symptoms are more severe is ingestion or inhalation are associated with exposure to other hydrocarbons which may potentiate the effects. Acute exposure to considerable concentrations of n-hexane may cause cough, wheezing, bloody frothy sputum, headache, dizziness, tachycardia and fever. Gastrointestinal symptoms may result. Respiratory system: slow and shallow respiration; aspiration of n-hexane may cause pulmonary edema and chemical pneumonia. Cardiovascular system: tachycardia and ventricular dysrhythmia. Central nervous system: vertigo, giddiness, CNS depression syndrome. In heavy exposures unconsciousness may result. Peripheral nervous system: chronic exposure may produce important peripheral neuropathy (motor sensory) and CNS abnormalities. Gastrointestinal tract: nausea, vomiting and anorexia. Hexane is poorly absorbed by the gastrointestinal system. Dermal absorption is very slow. Peak blood levels occur in less than 1 hour following inhalation or percutaneous exposure. N-Hexane has great affinity for high lipid content tissues and is rapidly metabolized to hydroxylated compounds before being converted to 2,5-hexanedione. Animal tests have been negative for teratogenic effects.

Flammability and Explosibility

Hexane is highly flammable. Vapor/air mixtures are explosive.

Documentation of Training – SOP Use of Hexane(s)

(signature of all users is required)

- Prior to conducting any work with hexane(s), you must have received training specific to the hazards involved in working with this substance.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

This page intentionally left blank

SOP Template: High Hazard Lab Operations

This blank template is for developing SOPs for any “high-hazard” chemical operations not covered by the template for Use of PHS. **The development of lab-specific SOPs for high hazard operations is the responsibility and determination of the supervisor.** OSHA does not have specific requirements for SOP content. EH&S recommends that the following elements be considered in SOP development, but supervisors should expand on as appropriate.

Date of last revision to SOP:

Scope of SOP

SOPs can be based on a specific chemical; a class of chemicals; a specific or set of lab procedures; a specific piece of equipment, etc.

Approval Required

Discuss any circumstances under which this operation requires prior approval.
E.g.“undergraduates can not do this operation without my specific consent”.

Hazardous Chemicals

List chemicals and their hazard class, e.g.,“carcinogenic, highly toxic, flammable, teratogen, corrosive, etc.” Better yet, print and attach LCSS or SDS (see Resources section for sources)

Chemical Name	Hazard Class

Personal Protective Equipment

List specific personal protective equipment needed, e.g., gloves, coats, eyewear. If a respirator is needed, contact EH&S (x8787).

EH&S webpage with Glove Reference Chart to Identify the Proper Gloves:

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp/sec2/selecting-proper-gloves

Engineering/Ventilation Controls

Describe required engineering controls. Examples: fume hoods glove boxes, biosafety cabinets, pressure relief valves, leak detection systems, auto-shut off valves, etc.

Any Special Chemical Handling, Storage, Cleanup or Disposal Requirements

Other

Documentation of Training

(signature of all users is required)

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

This page intentionally left blank

SOP: Chemical Storage

Date of last revision to SOP: Aug. 2014 – Kai Ewert

Basic Instructions

Proper chemical storage is essential in assuring a safe laboratory environment. Incompatible materials must always be separated in storage. Chemicals must be stored in a way that does not create additional hazards in the event of an earthquake.

Chemicals should be stored safely when not in actual use, so as not to create a tripping / spill / breakage hazard. It is the responsibility of each person who uses chemicals to ensure that they are **put away safely** when they are done using the chemicals **each day**.

Fume hoods are not storage areas and should not be used as such.

Any volatile solvents, chemicals or explosive gases requiring refrigeration in open or sealed containers must be stored in the designated “Flammables” fridge/freezer in room 1012.

Vented chemical storage cabinets are available under most fume hoods in room 1012 and 1024. Use these cabinets for storage of all hazardous chemicals which do not require refrigeration, and preferably for any chemical storage.

We have a large inventory of chemicals. To avoid buying chemicals that we already have in the lab, look in the chemical storage areas and check with Kai **before ordering a new chemical**. Some chemicals are also available via the surplus chemical program from other groups at UCSB who no longer need them (see the program’s website at http://www.sustainability.ucsb.edu/labrats/labrats-programs/labrats-surplus-chemical-program/). Consider "borrowing" a small quantity of material from another lab at the MRL or UCSB before buying it. Besides saving money and storage space, this sharing can save weeks in executing an experiment. Only **order the minimum amount that is sufficient to meet your needs**, even if the large quantities are cheaper per unit weight/volume.

It is best practice to label new chemicals with your initials, date received, and date opened (e.g. “KE Rcd. 9/09, Op. 10/09”). This is mandatory for **time-sensitive chemicals**, most prominently ether solvents (THF, diethyl ether). These must be used or disposed of within 6 months of opening. See also the EH&S fact sheet on time sensitive chemicals in Appendix A. Lab users who discover a time-sensitive chemical that is past due must take action to get it out of the lab and to campus EH&S for proper disposal. Contact Kai Ewert if you require assistance with this process.

Proper Segregation of Incompatible Chemicals

Always segregate chemicals according to their hazard class and incompatibilities. Incompatible chemicals (e.g. acids and bases, oxidizers and fuels) must not be stored together. If keeping them in separate cabinets is not feasible, place one group of chemicals in a plastic tub large enough to contain the chemicals if the containers break.

We separate our chemicals into the following categories. New materials may require additional categories.

- Flammable materials
- Acids
- Bases
- Salts and solids
- Organic reagents

If you are not sure what category some chemical is, ask Kai Ewert. See also the EH&S fact sheet on chemical storage in Appendix A.

Compressed Gas

Gas cylinders possess all the hazards of the chemical within as well as the hazards of a highly compressed gas.

All gas cylinders must be secured with at least one welded link chain unless they are in the process of being moved. Two chains, at 1/3 and 2/3 of the height of the cylinder, are better. Cylinders must not be moved unless the regulator has been taken off and the metal cap screwed in place.

Users of oxygen cylinders must be constantly aware that pure oxygen is a powerful oxidizer, making many compounds that otherwise burn slowly or not at all burn vigorously (e.g. plastic tubing)!

Additional Information

For additional information, see the EH&S fact sheets on chemical storage, compressed gas cylinders, peroxides, and time sensitive materials in Appendix A. These are also available on the web at

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/fact-sheets

SOP: Preparing For a New Project

Date of last revision to SOP: May 2022 (Kai Ewert)

Campus EH&S, the MRL, and lab supervisors do their best to ensure safety and provide crucial resources to help understand and mitigate any work-related hazards. However, due to the fluid and changing nature of the work performed in an academic setting, ultimately each individual is responsible to ensure that their work is safe for them and everyone nearby.

Before undertaking a new project, lab workers must do whatever research is required to understand the hazards associated with that work. For postdocs and graduate students supervising or mentoring more junior lab members, it is the responsibility of the mentor to make sure that the person supervised understands those hazards, too.

All new projects should begin by considering the health and safety hazards of the materials involved. Safety Data Sheets (SDS; formerly known as Material Safety Data Sheets/MSDS) and LCSS (if available) are good place to start (see the “Resources” and “Identifying Chemical Hazards” parts of this section of the CHP). For chemistry work, an educated guess of what the evolved gases, intermediate compounds, and final products will be is necessary to investigate their hazards as well. If you're not capable of making an educated guess, find someone who is well-acquainted with the chemistry or do a literature search.

If working with chemicals, check if the molecules contain high-energy functional moieties such as azide, nitro, or peroxide groups. Such functional groups may cause the molecule to decompose explosively when exposed to heat or (sometimes even mild) mechanical shock.

Pay particular attention to flash points, inhalation hazards, explosive materials, or air/water sensitive materials. Also be aware of potential chemical incompatibilities that may lead to violent reactions (see also the information / SOP on chemical storage). Determine the appropriate level of personal protective equipment, and match or exceed that level when performing the work.

For all new projects, try to find someone who is doing or has done similar work and get their input. Do not simply emulate their techniques and safety standards, however. Instead, ask questions and form your own opinion.

Get educated on the proper use of any unfamiliar equipment which the new work may require you to use.

Consider what waste the project will generate. If necessary, set up any required new waste containers (see the chemical waste information in this CHP and ask Kai Ewert if you need assistance).

Risk Assessment (from EH&S)

Note: A risk assessment template and two examples are provided in Appendix H.

Risk assessment should be conducted when introducing new equipment or procedures in your lab. It begins with identifying the hazards at each step of the process.

What is a hazard? A hazard is potential for harm.
And a risk? A risk is the probability that a hazard will cause harm.
Risk has two components - likelihood of a hazard causing harm and the severity of that harm.

Risk Assessment in the lab can be broken into four phases:

Recognize the Hazard
This is **Phase 1** of the assessment. This phase will identify the scope of work and potential hazards associated with each activity. What are the tasks that must be performed and what are the hazards associated with these activities, considering all aspects of health, safety and environmental hazards (e.g. chemical and biological spills and exposures, physical hazards such as high noise, moving parts, hot surfaces, etc.).

Assess the risk
This is **phase 2** and is associated with researching the potential hazards and risk associated with performing the work: Discuss with the team or the PI routine and infrequent tasks, near misses, and safety concerns; Learn more about the hazards of all materials and chemicals involved in the experiment. Your goal is to discover the following information before starting your experiment or project:

- What are the inherent hazards of the materials, equipment, and activity?
- What can go wrong?
- How could it happen?
- What are the worst-case scenarios?
- What are the contributing factors?
- Where it would happen (environment)
- Who or what it would happen to (exposure)

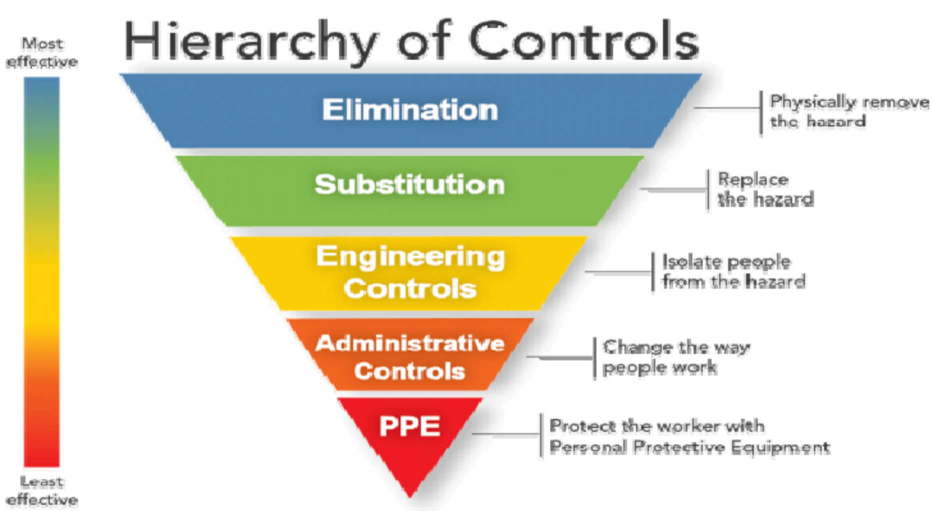
You can visualize the results of your risk analysis by utilizing a Probability and Severity **Risk Matrix** (see below). It will help you to minimize the probability of potential risk.

		Severity of Consequences – Personnel Safety			
Likelihood of Incident Occurrence		No injuries	Minor Injury	Significant Injury	Life threatening
	Very Likely	Low	High *	Unacceptable **	Unacceptable **
	Likely	Low	Medium	High *	Unacceptable **
	Possible	Low	Medium	High *	High *
	Rare	Low	Low	Medium	High *

Hazard Risk Level	Action
Unacceptable **	**STOP!** Additional controls needed to reduce risk. **Consult with PI.**
High *	Additional controls recommended to reduce risk. **Consult with PI.**
Medium	Ensure you are following best practices. Consult with peers, PI, and EH&S as needed.
Low	Perform work within controls

The results of the evaluation above should guide you in the selection of risk management techniques including elimination, substitution, engineering controls, administrative controls, and personal protective equipment. **This is known as the Hierarchy of Controls and defines Phase 3 of the risk assessment – Minimize the Risk**

Minimize the Risk:



The most preferred method of controlling risk is to <u>eliminate the hazard</u> altogether. In most cases, elimination is not feasible and when possible, **substitution** is the best approach to hazard mitigation. When possible, substitute less hazardous agents in place of their more hazardous counterparts. This also applies to conditions and activities. Examples include

- substituting toluene for benzene,
- non-lead-based paints for lead-based ones, or
- SawStop table saws for existing traditional table saws.

Engineering Controls consist of a variety of methods for minimizing hazards, including process control, enclosure and isolation, and ventilation (e.g. fume hoods, biosafety cabinets, glove boxes, etc.).

Administrative controls are controls which alter the way work is performed. They may consist of policies, training, standard operating procedures/guidelines, work scheduling, etc. These controls are meant to minimize the exposure to the hazard and should only be used when the exposure cannot be completely mitigated through elimination/substitution or engineering controls.

Personal Protective Equipment (PPE) should always be used as a last line of defense and is an acceptable control method when engineering or administrative controls cannot provide sufficient protection. PPE may also be used on a temporary basis while engineering controls are being developed.

Even with the best efforts to minimize risks, incidents can still happen. The last part of the Risk Assessment process, **phase 4** is **Prepare for what can can go wrong**.

Prepare for what can can go wrong
It is essential to anticipate the types of incidents that can occur and prepare in advance for them.

For example, if you are working with a flammable material, a fire is a possible incident. Knowing the appropriate evacuation routes from your lab and building, having appropriate material at hand to smother small fires, and pre-positioning a fire extinguisher in the lab (and getting the training necessary to use it effectively) are all appropriate emergency preparedness actions.

<u>Remember the acronym RAMP!</u>
Taking the time to perform risk analysis prior to each **new** experiment and procedure will contribute not only to the health and safety of you and your peers, but also will optimize the process and will lead to more productive research.
The University of Washington has developed a Risk Assessment Tool, which can help you through the process. As usual the EH&S Lab Safety division is here to support you and answer questions.

SOP: Chemical Spill Cleanup

Date of last revision to SOP: Nov. 2016 (Kai Ewert)

First things first

Call 9-911 if there is a fire, personal injury, or danger to life or property.

- Assess the extent of danger
- Help contaminated or injured persons
- Evacuate the spill area
- Avoid breathing vapors
- If possible, confine the spill to a small area using a spill kit or absorbent material.
- Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).

Be prepared

- Spill prevention is much better than spill cleanup
- Know the location of fire extinguishers, emergency showers, and eyewash stations
- Know the location of PPE and spill kits

Chemical Spill Cleanup Procedure

You should **NOT** clean up a spill if:

- The spill presents an immediate fire hazard
- You don't know what the spilled material is
- You are unsure about your ability to clean up the spill
- You lack the necessary skills, protection or equipment to clean the spill safely
- The spill is too large to contain
- The spilled material is highly toxic
- Exposure to fumes would result in physical injury
- You feel any symptoms of exposure

(Example: a mercury spill due to a thermometer that has dropped to the floor)

Instead, do the following in these cases

- alert other workers in the lab
- evacuate the area
- Call 9-911 if spill is immediately health-threatening
  or else

- Call x3194 (EH&S 24 hr assistance line; you may have to wait up to 15 min for a call back if it is after regular work hours)
- Notify Kai Ewert (805 252 4318)

If it is safe to clean up the spill then follow the steps below for cleanup

Evaluate and Notify

- Assess the toxicity, flammability, and other hazardous properties of the spilled material (if necessary, see labels and / or SDS – safety information resources are provided in this CHP)
- For flammables, remove or turn off all ignition sources such as open flames, motors, pumps, fridges
- Notify other workers in the area
- Notify Kai Ewert or Youli Li as soon as safely possible

Contain and Clean Up

- Wear two layers of gloves, eye protection, and a lab coat. Consider wearing highly impermeable (but “clumsy”) barrier gloves. Wear a face shield (available in the lab, typically on a rack next to the hood housing chemical waste) if you deem it necessary
- Contain and absorb spill using absorbents appropriate for the material (e.g. paper towels, kim wipes, or materials from the spill kit located in room 1012, in the cabinet under the sink next to the hood)
- For volatile materials, focus on minimizing the generation of vapors by transferring soaked adsorbents and adsorbed materials into a fume hood as quickly as possible
- Package waste in a tight-closing container and label it. Include contaminated gloves, clothes, rags, equipment, etc. Store the container with the chemical waste or temporarily in a separate fume hood if necessary.

Follow Up

- Arrange for the waste to be picked up by EH&S as soon as practical. Contact the lab member responsible for chemical waste disposal or Kai Ewert if you are unfamiliar with the procedure
- Reorder and restock the used cleanup materials if necessary
- Inform EH&S if any personnel was exposed to hazardous chemicals, or if there was release of hazardous material to the drain system
- If there was a significant injury, follow the procedures outlined in the blue emergency flip-charts located in every MRL office and lab (next to the door) under the heading "MEDICAL EMERGENCY" (also listed above, page 16, under “In the Event of an Injury”).

SOP: Evacuated Glass Apparatus

Date of last revision to SOP: Aug. 2014 (Kai Ewert)

Scope of SOP

This SOP applies to any evacuated glass, or glass apparatus with a reduced pressure on the inside. Important examples in the lab are rotary evaporators (rotavaps), the cold traps of the vacuum setup, vacuum distillation, and Schlenk lines. Permanently sealed dewars (for holding cryogens) also are evacuated glassware and must always be handled with care.

Hazards

Evacuated glassware can implode if the surface is flawed, and if exposed to physical or thermal shocks, posing a severe risk of injury from flying shards of glass.

Required personal protective equipment

> It is imperative that anyone evacuating glass **wear eye protection** such as ANSI-approved safety glasses, goggles or face shields.

Whenever feasible, evacuated glassware should be contained in a fume hood with the sash lowered.

Preventative measures

Glassware that is intended for evacuation should always be handled carefully to prevent scratches, cracks or chips.

Glassware that is to be evacuated must be inspected **before every use** to ensure that it does not have any cracks or chips that would be weak spots inviting implosion. Watch for small "stars", localized star-shaped cracks that can result from setting glassware down on hard surfaces. Mark cracked or chipped glassware and consult the glassblower so see if it can be repaired.

Whenever feasible, evacuated glassware should be covered with plastic mesh, a polymer coating or a covering of (e.g. electrical) tape to minimize release of shards in the event of an implosion.

Documentation of Training – SOP Evacuated Glass Apparatus

(signature of all users is required)

- Prior to conducting any work with evacuated glass apparatus, you must have received training specific to the hazards involved.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

SOP: Enclosed Glass with Cryogenic Cooling

Date of last revision to SOP: May 2022 (Kai Ewert)

Scope of SOP

This SOP applies to evacuated glass cooled with cryogens (typically liquid nitrogen or isopropanol/dry ice). The most important application of such a setup in the lab are cold traps, e.g. to protect a vacuum pump from vapors.

Hazards

Cryo-cooled glassware poses all the hazards of evacuated glassware (see also the SOP for Evacuated Glass Apparatus): evacuated glassware can implode if the surface is flawed, if exposed to physical or thermal shocks, posing a severe risk of injury from flying shards of glass.

In addition, cryogenic cooling adds other serious hazards. Oxygen can condense at cryogenic temperatures and collect in the apparatus as a blue liquid, e.g. if the cryo-cooled cold traps are open to air without a vacuum being applied. Liquid oxygen, which accumulates preferably because it is less volatile than nitrogen, is a powerful oxidizer which turns many organic materials (e.g. charcoal or sawdust!) into explosives. If a closed cryo-cooled glass apparatus is allowed to warm to room temperature, condensate may rapidly vaporize, resulting in a rapid pressure buildup and possibly explosion of the glass apparatus. Additionally, cryogens as well as surfaces cooled by these pose an injury hazard due to their very low temperature. Cryogens also cause many materials to become very brittle and thus more susceptible to mechanical damage.

For a description of a recent incident with lessons learned, see:
https://researchsafety.northwestern.edu/safety-information/glass-vacuum-trap-safety-alert.html

See also the EH&S Fact Sheet on Cryogens in Appendix A.

Required personal protective equipment

Suitable **eye protection**, such as ANSI-approved safety glasses, goggles or face shields, is mandatory.

Appropriate gloves must be worn when **handling cryogens**. A pair of gloves for handling of cryogens should be available near the -70 °C freezer in room 1032.

Other safety precautions

Whenever feasible, cryo-cooled glassware should be contained in a fume hood with the sash lowered.

Everyone using cryogenically chilled glass vessels must be vigilant, checking for leaks and condensates, especially oxygen from air. If condensation of oxygen (accumulation of a blue liquid) is observed, the procedure must be stopped; the apparatus must be vented to air, and allowed to warm to room temperature in a fume hood.

Any vessel that has been cryogenically cooled and evacuated must only be warmed slowly and should be vented while warming to allow condensates to evaporate slowly.

Documentation of Training – SOP Enclosed Glass with Cryogenic Cooling

(signature of all users is required)

- Prior to conducting any work with enclosed glass apparatus with cryogenic cooling, you must have received training specific to the hazards involved.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP.

I have read and understand the content of this SOP, and have received any additional specific training that I deem necessary:

Name	Signature	Date

SOP: Use of Pyrophoric and Water-Reactive Materials

Date of last revision to SOP: Apr. 2023 – Kai Ewert

Scope of SOP

Use of materials (solids, liquids, or gases) that are pyrophoric (ingnite spontaneously in air) and/or are highly reactive with water. Commonly used examples include:

- Alkyl-lithium reagents and their solutions, e.g. *n*Bu-Li, *t*Bu-Li
- Grignard reagents (R-Mg-X) and their solutions
- Metal hydrides, e.g. sodium hydride NaH and lithium aluminium hydride $LiAlH_4$
- Alkali metals, e.g. sodium, potassium

Approval Required

Before using pyrophoric and/or water-reactive materials, any laboratory worker (student, postdoc, or visiting researcher) **must obtain approval from Prof. Safinya in writing**, by way of their Training Needs Assessment or an email to the Safety Delegate (Kai Ewert).

Hazard Information

Pyrophoric and Water-Reactive Materials are among the most hazardous materials in our laboratory (aside from extremely toxic and carcinogenic materials).

In general the materials covered by this SOP may ignite spontaneously when exposed to air or ambient moisture. They also tend to be associated with flammable solvents which they may ignite upon exposure to air or moisture. Moreover, many of these materials produce highly flammable gases when exposed to water. Other common hazards include corrositivity, water reactivity, peroxide formation, and toxicity.

Training Required

In addition to this SOP, users of pyrophoric and water-reactive materials must read the documents provided in Appendix G.
Users must undergo specific hands-on training prior to working with these materials. Users should be supervised when performing this work until they have demonstrated proficiency in safe handling of pyrophoric and water-reactive materials (at least once). This training shall be documented in the Training Needs Assessment of the lab user.

Risk Assessment Required

Users must complete a Risk Assessment prior to using pyrophoric and water-reactive materials. A risk assessment template and two examples are provided in Appendix H.

General Precautions

Before working with pyrophoric and water-reactive materials, refresh your memory on safe handling procedures (see below) and read the relevant Safety Data Sheets (SDS) and understand the hazards. The SDS must be reviewed before using an unfamiliar chemical and periodically as a reminder.
Users of pyrophoric and water-reactive materials must not work in the lab alone. At least one other person must be present in the laboratory. Ideally, restrict this work to regular work hours (Monday – Friday from 8 am to 5 pm), when safety staff are on campus.
Set up your work in a laboratory fume hood or glove box and ALWAYS wear the appropriate PPE. Remind yourself of the nearest location of eyewash and emergency shower stations. Avoid contact with skin, eyes and clothing. Avoid inhalation of vapor or mist. Wash hands before breaks and immediately after handling pyrophoric and water-reactive materials.

Personal Protective Equipment

Users handling pyrophoric and water-reactive materials must employ the following personal protective measures:

- **Protective gloves**

  Common lab gloves (nitrile, latex) are not permitted for work with pyrophoric and water-reactive materials. Users must wear neoprene gloves over Kevlar liner gloves. A stock of these is available in room 1032 and they are carried by the chemistry store room.

- **Protective eyewear**

  ANSI-approved, tight-fitting safety glasses/goggles must be worn at all times. For procedures with splash potential, a face shield (available in the lab on the side of the single hood in room 1024) should be used.

- **Lab coat etc.**

  Use of a flame-resistant ("blue") lab coat is required. Long pants or equivalent as well as closed-toe shoes are mandatory.

Engineering/Ventilation Controls

Many pyrophoric chemicals release noxious or flammable gases and should be handled in a laboratory **fume hood**. In addition, some pyrophoric materials are stored under kerosene (or other flammable solvent), therefore the use of a fume hood (or glove box) is required to prevent the release of flammable vapors into the laboratory. Use on the open bench (aside from rapid weighing of solids) is prohibited.

When containers with pyrophoric and water-reactive materials are removed from the fume hood, these containers must be sealed.

Special Requirements for Purchasing, Storage, Handling, Cleanup and Disposal

- **Purchasing**

Discuss any planned purchases of pyrophoric and water-reactive materials with Kai Ewert. You must receive approval of the risk assessment for working with the material from Prof. Safinya, Kai Ewert, or Amanda Strom before placing your order.
Only order the amount required – no bulk or multiple purchases. These materials do not keep long and disposal is a high hazard operation.

- **Storage:**

Pyrophoric and water-reactive materials must be stored under an inert atmosphere (or under kerosene as appropriate) in completely-sealed containers in the fridge designed for storage of flammables or in one of the chemical storage cabinets underneath the fume hoods.
The storage location must be physically separated from any flammable solvents and/or waste containers, i.e. not in the same hood and not in the same flammable cabinet. The storage location must also be away from heat/flames, oxidizers, and water sources.
All other standard storage precautions (see SOP on Chemical Storage) apply.

- **Handling**

For proper handling of pyrophoric and water-reactive materials, refer to the information provided in Appendix G and the required hands-on training. Contact Kai Ewert with any questions.

If reactions are left unattended, a sign should be posted with hazards noted.

For additional resources, including a link to a video demonstrating handling of pyrophoric liquid (which will bring up several similar videos), see

https://drs.illinois.edu/Page/SafetyLibrary/PyrophoricMaterials

(video link: https://youtu.be/iLMI10X0Naw; procedure starts at 9:00)

- **Spills/Cleanup:**

Spills of pyrophoric and water-reactive materials are extremely dangerous. Always make safety of users involved and in the vicinity a priority.

Exert extreme caution due to potential spontaneous combustion!

Exert extreme caution due to potential ignition of flammable solvents or other materials.

If anyone is exposed, or on fire, wash with copious amounts of water, ideally in the lab shower.

Small Spill

- Call for a coworker to provide backup.
- Place a fire extinguisher nearby.
- Carefully remove nearby flammable materials.
- Powdered lime (calcium oxide, CaO) or dry sand should be used to completely smother and cover any spill that occurs.
- Carefully quench by slow addition of isopropanol.
- After complete quench, double bag spill residues for hazardous waste pickup.
- Call 9-911 or x3194 for emergency assistance if necessary.

Large Spill

- If anyone is exposed, or on fire, wash with copious amounts of water, ideally in the lab shower.
- Call 9-911 and/or x3194 for emergency assistance.
- Evacuate the spill area.
- Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering.
- Provide emergency personnel with technical advice on the chemicals involved.

- **Firefighting Measures**

A container of sand or powdered lime (calcium oxide, CaO) should be kept within arm’s length when working with a pyrophoric material. The sand or lime can be used to smother small fires from spilled materials, including burning metals, and can also be used to extinguish e.g. a needle-tip contaminated with pyrophoric material that ignites.

In addition, the labs fire extinguishers can be used. Both the carbon dioxide fire extinguisher (by the exit door of room 1012) and the dry chemical fire extinguishers (by all lab exit doors) can be used on fires involving liquids or gases. This typically includes fires ignited by a small amount of pyrophoric solid.

Metal fires require special (Class D) fire extinguishers. These are not present in the lab, so if the risk assessment shows the potential for a fire largely consisting of a flammable metal (e.g. lithium, sodium, magnesium), discuss the planned procedure with Kai Ewert.

- **Disposal**

All pyrophoric and water-reactive materials must be “neutralized” or “quenched” prior to entering the chemical waste disposal process like other chemical waste. The precise treatment for “neutralization” varies based on the nature of the material but always Find an appropriate procedure from the literature, consult Kai Ewert and have him assist you in the neutralization.

The flammability of the pyrophoric and water-reactive materials and the highly exothermic nature of their reactions with e.g. alcohols and water make neutralization a high hazard operation. Therefore, extreme caution is required and the procedure needs to be performed in a hood that has been cleared of anything unrelated to the neutralization procedure (flammables in particular).

Once properly neutralized, the remaining waste may be segregated, stored, and disposed of in the same manner as other chemical waste (see the dedicated section in this CHP).

Documentation of Training – SOP Use of Pyrophoric and Water-Reactive Materials

(Signature of all users is required)

I have read and understand the content of this SOP and the materials in Appendix G. I will only use pyrophoric and water-reactive materials after I have completed the required hands-on training and have received written permission by Prof. Safinya.

Name	Signature	Date

Appendix A: EH&S laboratory safety fact sheets

The following EH&S laboratory safety fact sheets are attached (accessed via https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/fact-sheets; all are current as of the latest revision of this CHP):

- Azides, Handling Organic
- Benzene
- Centrifuge
- Chemical Storage
- Chemical Waste
- Chlorinated Solvents
- Compressed Gas Cylinders
- Cryogens
- Dichloromethane
- Electrophoresis
- Ethidium Bromide (https://www.ehs.ucsb.edu/sites/default/files/docs/hw/ethidium_bromide.pdf)
- Formaldehyde
- Housekeeping Guide for labs
- Nanomaterials
- Peroxides
- Power Failures Guide
- Refrigerator & Freezers in Lab
- Seismic Hazard Reduction
- Time-Sensitive Chemicals

This page intentionally left blank

LABORATORY SAFETY FACT SHEET #26

Synthesizing, Purifying, and Handling Organic Azides

Organic azides are potentially-explosive substances that can and will decompose with the slightest input of energy from external sources (heat, light, pressure). Additionally, small molecules containing the azido functionality tend to decompose violently which may result in injury if proper safety precautions are not utilized.

Organic azides have received renewed interest for their shear diversity of potential organic transformations but also in no small part to the recent introduction of the concept of 'Click Chemistry.'[1] This renewed interest must be paralleled with a reiteration of the safety precautions one must undertake. In addition to summarizing the multitude of these synthetic transformations in which azide can participate, recent reviews have also outlined safety precautions one should take when utilizing these energy-rich molecules. These manuscripts should be mandatory reading for anyone working with, or around azides.[2]

Obtained by simple nucleophilic displacement of a halogen or by copper (I)-catalyzed aryl coupling, organic azides can be prepared, purified, and handled safely provided one takes the following precautions:

NaN_3:

- Azide ion has a similar toxicity as that of cyanide ion (LD_{50} = 27 mg/kg for rats). Be sure to use appropriate gloves when weighing azido salts.

- Sodium azide reacts violently with several common laboratory organics such as: CS2, bromine, Bronstead acids, and heavy metals. When attempting a new reaction, be relentless in your background research to determine the reactivity of sodium azide to ALL reaction components.

- NEVER use chlorinated solvents as reaction media! Utilizing dichloromethane or chloroform will result in the formation of explosively-unstable di- and tri- azidomethane, respectively (refer to section on C/N ratios below).

- Heavy metals (e.g., Cu, Pb, Ba) form shock and pressure sensitive compounds with azide anions. This may affect us in that an 'azide residue' may form of metal parts.

Organic Azides:

- All organic azides decompose with introduction of external energy. Any azide synthesized should be stored below room temperature (-18°C) and in the dark.

- When designing your target azide, keep in mind the following equation.[1] Notice that this equation takes into account all nitrogen atoms in your azide, not just those in the azido group. *N* signifies the number of atoms.

$$\frac{N_C + N_O}{N_N} \geq 3 \qquad \text{(eq. 1)}$$

- In practice, organic azides that contradict the above equation can be made, and in some cases, be stored safely. Consider the following points as strict guidelines in the preparation and storage of organic azides. As with all synthetic procedures a small scale (ca. 0.5-1.0 gram) should be run first to determine the nature of the product:

  - *n*-nonyl azide (C/N=3) will be the smallest azide isolated and stored in its pure form. This azide, when stored properly, can be done so in multigram quantities (up to 20 grams). In practice, the octyl derivative is equally safe (C/N=2.7).

  - Azides smaller than C/N=3 (but greater than C/N=1) can be synthesized and isolated, but by no means should these molecules be stored in its highest purity. Rather, if storage is necessary store these azides as solutions below room temperature (concentrated to no more than 1M, less than 5 grams material).

  - Under no circumstances should azides with C/N < 1 be isolated. However, these molecules may only even be considered for synthesis if the azide is a transient intermediate species, AND the limiting reagent in the reaction mixture, AND with maximum quantities of 1 grams. For instance, methyl azide can be synthesized in situ and immediately reacted with an excess of a terminal acetylene.[1]

- Never use distillation or sublimation as purification techniques! Purification should be limited to extraction and precipitation. Column chromatography may contribute to decomposition so only purify azides that satisfy equation 1.

- Organic azide waste should be placed in a separate, explicitly-labeled container designated solely for azide waste. Extra caution must be taken to make certain that azide waste not come in contact with acid. Acids will protonate the azide ion and from the highly-toxic hydrogen azide (toxicity similar to that of hydrogen cyanide).

---

[1]. Kolb, H.C.; Finn, M.G.; Sharpless, K.B. *Angew. Chem. Int. Ed.* **2001**, *40*, 2004-2021.
[2]. Brase, S.; Gil, C.; Knepper, K.; Zimmerman, V. *Angew. Chem. Int. Ed.* **2005**, *44*, 5188-5240. And all references therein.
[3]. Smith, P.A.S. Open-Chain Nitrogen Compounds, vol. 2, Benjamin, New York, 1966, 211-265.
[4]. Feldman, A.K.; Colasson, B.; Fokin, V.V. *Org. Lett.* **2004**, *6*, 3897. Thibault *et al.* manuscript in preparation

LABORATORY SAFETY FACT SHEET #28

Benzene

Exposure to benzene puts you at increased risk of developing leukemia and other blood disorders. It can effect the central nervous system and cause irritation to the respiratory tract and skin/eye. Exposure may occur through inhalation, skin absorption or ingestion**.**

Benzene is one of few chemicals with a **specific regulatory standard** written to protect workers. *Cal-OSHA Permissible Exposure Limits* for benzene (see below) are very low and violations of the standard can result in fines. To remain below the benzene PEL, workers **must always work in a fume hood, glove box or with sealed containers** and in conjunction with adequate personal protective equipment. It is the **responsibility of the lab supervisor/PI** to ensure that all legally-required protections are in place and understood by their workers. Contact EH&S if your lab can not meet these requirements.

Exposure Hazards of Benzene

Long-Term Effects of Exposure

Animal studies and the occurrence of disease in human work forces show a linkage between benzene exposure and cancer, including **leukemia -** plus other blood disorders like anemia. It is listed as a **known human carcinogen** by the *International Agency on Research of Cancer* and the *National Toxicology Program*.

Short-Term Effects of Exposure

- *Inhalation* - benzene is volatile and inhalation is therefore a major route of exposure. Low-level exposures can cause **dizziness, headache, nausea, and irritation to the respiratory tract**. Other symptoms can include feelings of breathlessness, irritability and euphoria. High exposures can cause convulsions or coma. The **odor threshold** for benzene is 60 ppm, although individual sensitivity will vary. However, given that toxic effects will occur at much lower levels (see below), lack of odor can not be used as an indicator of safety.

- *Skin contact* - may irritate skin. Can cause **dermatitis** (chapping, drying, rashes) on repeated contact with skin.

- *Eye contact* – vapors irritate the eyes, with eye splash causing serious irritation.

Cal-OSHA Legal Limits for Exposure

- *Permissible Exposure Limit (inhalation):* 1 ppm (8 hr time weighted average)
- *Short-term Exposure Limit (inhalation):* 5 ppm (15 minutes)
- *Action Level (inhalation): 0.5 ppm*

If EH&S believes your exposure to benzene may exceed these levels, UCSB must monitor your exposure level. If monitoring confirms that your exposure is above-limits, then a medical surveillance program must be made available to you at no cost, and/or we must reduce your exposure below these limits.

Controlling Exposures

Engineering Controls

Benzene should *never* be used without adequate ventilation. It should always be used in a properly functioning **fume hood, glove box or in a sealed system**.

Protective Equipment and Clothing

- *Gloves* – the gloves commonly found in campus labs/storerooms (nitrile, neoprene and latex) are **not recommended** for use with benzene due to the ease with which it permeates through those glove materials. The recommended gloves are "Silver Shield", polyvinyl alcohol, Viton, or "Barrier" (available from vendors like Fisher Scientific). Some of these gloves have poor dexterity characteristics, but their utility can be increased by wearing a more dexterous glove over the inner glove.

- *Eyewear* - safety glasses or goggles should be worn as with any chemical

- *Respirator* – if a fume hood is available then a respirator is not needed. If a respirator is needed for special circumstances, prior to using one, you must first contact EH&S (x-8787) to enter the UCSB Respiratory Protection Program to satisfy current Cal-OSHA requirements.

Other Requirements

Material Safety Data Sheets (MSDS) - Per Cal-OSHA, chemical-users users must know what MSDS are, their relevance to health and safety and how to readily access them. These issues are covered in the *EH&S Lab Safety Orientation*. Regular users of benzene should have a hard copy MSDS available - see the EH&S website for electronic access. The MSDS will cover the benzene issues above and many others (e.g. flammability, spill clean-up, etc.)

Chemical Hygiene Plan – Per Cal-OSHA, benzene is considered a **Particularly Hazardous Substance.** Therefore, its safe use must be addressed in your lab's written *Chemical Hygiene Plan* (CHP). Since many safety issues are addressed generically in this fact sheet, it can be used as a resource in developing your CHP. Lab supervisors/PIs should contact EH&S at x-4899 if you need an orientation to this requirement.

LABORATORY SAFETY FACT SHEET #19

Centrifuge Safety

1. Before using any centrifuge review the owner's manual- obtain a copy of the manual if it is not available. Check rotor for rough spots, pitting & discoloration. Consult manufacturer if discovered.

2. High speed rotor heads are prone to metal fatigue. Each rotor should be accompanied by its own log book indicating the number of hours run at top or de-rated speeds. Do not exceed the design mass for the maximum speed of the rotor. Failure to observe this precaution can result in dangerous and expensive rotor disintegration.

3. Make sure rotor, tubes and spindle are dry and clean and that the rotor is properly seated and secured to the drive hub. Tubes must be properly balanced in rotor (½ gram at 1 G is roughly equivalent to 250 Kg @ 500,000 G's).

4. Before use, tubes should be checked for cracks. The inside of cups should be inspected for rough walls caused by erosion and adhering matter should be removed. Metal or plastic tubes (other than nitrocellulose) should be used whenever possible.

5. Use sealed rotors, sealed buckets, or a guard bowl with gasketed cover as well as safety centrifuge tubes (tube or bottle carrier with sealable cap or "O" gasketed cap).

6. After use, tubes, rotors, and centrifuge interiors should be cleaned and disinfected.

7. If a tube breaks, the centrifuge should be turned off, allowed to stand undisturbed for 15 minutes before opening. Clean and disinfect the rotor. If infectious material was placed in the centrifuge, plan proper decontamination and cleanup.

8. Cleaning and disinfection of tubes, rotors and other components requires considerable care. No single method is suitable for all items, and the various manufacturers' recommendations must be followed to avoid rotor fatigue, distortion and corrosion.

9. Once run is complete, make sure the rotor has STOPPED before opening the centrifuge lid.

Infectious Materials

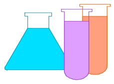
1. High- speed centrifuge chambers are connected to a vacuum pump. If there is a breakage or accidental dispersion of infected particles, the pump and pump oil will become contaminated. A HEPA filter should be placed between the centrifuge inner chamber and the vacuum pump when containment is needed.

2. Centrifuge tubes or bottles should only be filled, loaded into rotors, and removed from rotors from within a biological safety cabinet. This practice provides containment in case a tube or bottle leaks or breaks.

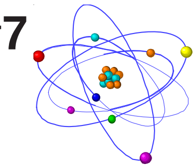
For further information, contact the EH&S Laboratory Safety Specialist at x-4899

This page intentionally left blank

LABORATORY SAFETY FACT SHEET #7



SAFE STORAGE OF CHEMICALS

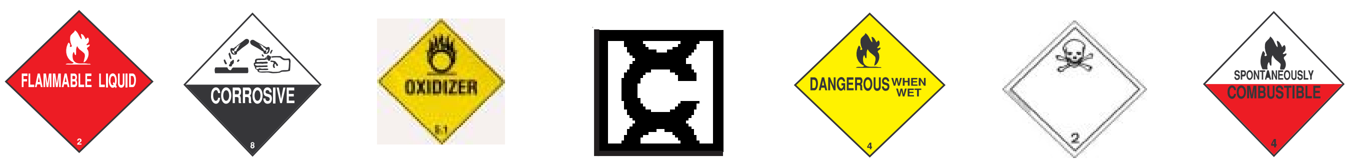


INTRODUCTION: If incompatible chemicals are inadvertently mixed a fire, explosion, or toxic release can easily occur. In earthquake-prone areas like Santa Barbara, it is particularly vital that chemicals be stored safely. Take steps now to prevent damage to your facility, or harm to lab personnel.

Below are some basic guidelines for chemical storage. Note however, that chemicals can often fall into more than one hazard category and therefore the chemical label and/or Material Data Safety Sheet (MSDS-*see below*) should be reviewed for specific storage requirements. Separate chemicals by adequate distance, or preferably by using physical barriers (e.g. storage cabinets). Avoid using the fume hood for chemical storage - this practice may interfere with the proper air flow of the hood. For especially dangerous materials, use a secondary container (e.g. plastic tub) large enough to contain a spill of the largest container.

Chemicals should be disposed based on - but not limited to - the following criteria: material has exceeded it's shelf life; the cap is deteriorating or the container is leaking; the container has inadequate hazard information; material is waste (by law all chemical wastes must be disposed of within one year).

BASIC HAZARD GROUPS



Flammables *Corrosives* *Oxidizers* *Carcinogens* *Water Reactives* *Toxics* *Pyrophorics*

With the wide variety of chemicals used in laboratories, the list below is prioritized for materials that are ***COMMONLY*** used in a research laboratory. This chart indicates the most obvious chemical incompatibilities, and provides a segregation plan. For more specific chemical incompatibility information, please consult the manufacturer's MSDS, available at **http://www.ehs.ucsb.edu/units/labsfty/labrsc/chemistry/lschemmsds.htm** or contact EH&S at X8243.

ACIDS

Acetic Acid
●Chromic Acid
Hydrochloric Acid
Hydrofluoric Acid
●Nitric Acid
Phosphoric Acid
Sulfuric Acid

●Indicates strong oxidizing acids, store per <u>oxidizers</u> section

<u>Storage Precautions:</u>

⇨Store bottles on low shelf areas, or in acid cabinets.
⇨Segregate oxidizing acids from organic acids, **AND** flammable materials.
⇨Segregate acids from bases, **AND** from active metals such as sodium, potassium, etc.
⇨Segregate acids from chemicals which could generate toxic gases such as sodium cyanide, iron sulfide, etc.

BASES

Ammonium Hydroxide
Potassium Hydroxide
Sodium Hydroxide

<u>Storage Precautions:</u>

⇨Separate bases from acids.
⇨Store bottles on low shelf areas, or in acid cabinets.

FLAMMABLES-fuels are reducing agents

Acetone
Benzene
Cyclohexane
Ethanol
Ethyl Acetate
Ethyl Ether
Gasoline
Hexane
Isopropyl Alcohol
Methanol
Propanol
Tetrahydrofuran
Toluene
Xylene

Storage Precautions:
⇨Store in approved flammable storage cabinet(s) (required if there is more than 10 gallons in the lab).
⇨Separate from oxidizing acids and oxidizers.
⇨Keep away from any source of ignition(flames, localized heat or sparks).
⇨Use only "flammable storage" (desparked) refrigerators or freezers.

OXIDIZERS-react violently with organics.

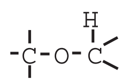
Solids
Calcium Hypochlorite
Ferric Chloride
Iodine
Nitrates, Salts of
Peroxides, Salts of
Potassium Ferricyanide
Sodium Nitrite

Liquids
Bromine
Hydrogen Peroxide
Nitric Acid
Perchloric Acid
Chromic Acid

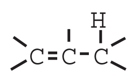
Storage Precautions:
⇨Keep away from flammables, organic solvents, and other combustible materials (i.e. paper, wood, etc.).
⇨Keep away from reducing agents.
⇨Store in a cool, dry place.

PEROXIDE-FORMING CHEMICALS-peroxides can be explosive and shock-sensitive.

Ethers and acetals with α-hydrogen


(e.g. ethyl ether, tetrahydrofuran)

Alkenes with allylic hydrogen


(e.g. cyclohexene)

For a more complete list of these materials visit our website at
http://www.ehs.ucsb.edu/units/labsfty/labrsc/lsflamable.htm#formers

Storage Precautions:
⇨Dispose before expected date of initial peroxide formation.
⇨Label containers with receiving, opening, and disposal dates.
⇨Store in airtight containers in a dark, cool, and dry place.

PYROPHORIC SUBSTANCES-spontaneously ignite in air.

Some finely divided metals
Some organoaluminum compounds ($LiAlH_4$, $Al(CH_3)_3$)
Silane
●Phosphorus, Yellow

●Phosphorus, yellow should be stored and cut under water

Storage Precautions:
⇨Rigorously exclude air and water from container.
⇨Store away from flammables.
⇨Store in a cool, dry place.

WATER REACTIVE CHEMICALS-reacts violently with water to yield flammable or toxic gases.

Solids
Calcium Carbide
●Lithium
Magnesium
●Potassium
●Sodium

Liquids
Phosphorus Trichloride
Thionyl Chloride

●Lithium, Potassium, and Sodium should be stored under Kerosene or Mineral Oil

Storage Precautions:
⇨Rigorously avoid exposure to water and air.
⇨Store away from flammables
⇨Store in a cool, dry place.

HIGHLY TOXICS, CARCINOGENS, REPRODUCTIVE TOXINS

These chemicals can be very hazardous by themselves, or in combination with other chemicals. If they are easily inhaled, (gases and volatile liquids) then they are particularly hazardous. Suspected human carcinogens should also be stored as highly toxic. Lists of these materials are provided on our website:
http://www.ehs.ucsb.edu/units/labsfty/labrsc/chemistry/lschem.htm

Gases - Store in a gas cabinet or other ventilated cabinet

Chlorine
Hydrogen chloride
Fluorine
Nitric Oxide

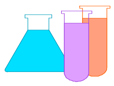
Liquids - Seal tightly and store in a ventilated cabinet apart from incompatibles. Use secondary containment (e.g. plastic tub) to contain any spills.

Formaldehyde
Nickel carbonyl
Carbon disulfide
Cyanide solutions
Mercury

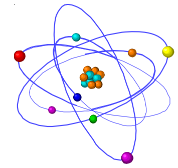
Solids -Store away from incompatibles (usually acids) that would release toxic gas upon contact.

Cyanides, Salts of
Sulfides, Salts of

LABORATORY SAFETY FACT SHEET #6



CHEMICAL WASTE DISPOSAL



REGULATIONS

- Hazardous waste regulations are stringent and penalties for violations can be severe. Santa Barbara County inspects UCSB labs for compliance on a regular basis.

STORAGE

- Store chemical waste in a designated area. Label area as, "**HAZARDOUS WASTE STORAGE AREA**"
- Store chemicals in containers compatible with, and durable enough for, the waste. Liquid waste must be in screw top containers. Do not overfill container, allow for expansion.
- Gas cylinders and lecture bottles must have regulators removed.

LABELING

- Identify waste by proper chemical name (no abbreviations or chemical structures). List chemical names of hazardous components in that mixture by percent weight.
- Deface existing labels when reusing containers.
- Label and date container(s) when the first drop of waste is added. Hazardous waste shall be disposed within ***9 months*** of start date.
- Use ***UCSB HAZARDOUS WASTE*** label on all hazardous waste containers. All portions of the label must be completed. Labels are available for free in all science storerooms.

University of California at Santa Barbara
Santa Barbara, California 93106
UCSB HAZARDOUS WASTE
Waste must be segregated, labeled and packaged according to the Campus Hazardous Waste Disposal Procedures.
Contact Name ____ Department: ______ Phone ______ Start Date: ____
Proper Chemical Name(s): ______________________________
Additional Content Information: ______________________________
Physical State: ☐ Liquid ☐ Solid ☐ Gas
Chemical Hazard Classification:
☐ Flammable ☐ Oxidizer ☐ Corrosive ☐ Reactive ☐ Toxic/Poison
In case of an emergency contact UCSB-EH&S at x3194

SEGREGATION: group waste into the following categories:

- halogenated organics (*dichloromethane, chloroform*)
- non-halogenated organics (*acetone, methanol, ethanol, xylene*)
- acids with pH 2 or less (*HCL, sulfuric acid*)
- alkaline solutions of pH 12.5 or greater (*sodium hydroxide*)
- alkali metals and other water reactives (*sodium, acetyl chloride*)
- heavy metal solutions and salts (*mercury, silver, zinc*)
- strong oxidizers (*nitric acid, chlorates, permanganates*)
- peroxide-forming chemicals (*dioxane, THF*)
- cyanides (*potassium cyanide, hydrogen cyanide*)
- chemical carcinogens (*acrylonitrile, inorganic arsenic*)
- unstable chemicals
- other toxic chemicals

DISPOSAL

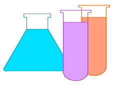
- Chemicals may not be disposed in regular trash, sink disposal, or allowed to evaporate.
- Complete a UCSB Waste Pick-up Request Form. Send either by campus mail or fax (X7259). Also available on EH&S website **http://ehs.ucsb.edu** for electronic submission.
  - *EH&S cannot accept responsibility for improperly labeled, packaged, and/or segregated chemicals, and will not pick them up.*
  - *Transfering waste into appropriate containers is the generators responsibility.*
  - *Waste containers become the property of EH&S and will not be returned.*
  - *Before working with hazardous material attend EH&S Lab Safety course, call X4899 for next available training date.*

CHEMICAL SPILL

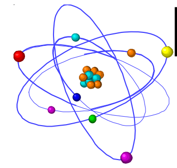
- Clean up a spill if you have the proper equipment and feel comfortable doing so. Otherwise, contact EH&S **24-hour line X3194**.

Further information contact EH&S Hazardous Waste Program X3293

This page intentionally left blank



LABORATORY SAFETY FACT SHEET #15



Chlorinated Solvents

Examples: methylene chloride, chloroform, trichloroethylene, dichloroethylene

Hazards

- Most of these compounds have an **anesthetic or narcotic effect**, causing people to feel intoxicated if overexposed. This can be particularly dangerous when working around machinery, as judgment and coordination can be impaired.
- Some of the chlorinated solvents are strong **systemic poisons** which damage the liver, kidneys, nervous system, and other organ system. These symptoms most often appear gradually, with nausea, loss of appetite, vomiting, headaches, weakness, and mental confusion most common.
- All chlorinated solvents can cause **dermatitis** (chapping, drying, rashes) on repeated contact with the skin, since they remove the protective fats and oils. Gloves appropriate for a particular chlorinated solvent should be determined by consulting a **glove reference chart** – see EH&S website under Programs/Lab Safety/Personal Protective Equipment.
- Many of the compounds are highly **irritating** to the membranes around the eyes, and in the nose, throat, and lungs. Examples of chlorinated solvents which have irritating properties are ethylene dichloride and chloroform.
- In studies on laboratory animals, many chlorinated hydrocarbons have been linked to the development of **cancer** in animals; examples of these compounds are: ethylene dichloride, perchloroethylene, chloroform and methylene chloride.
- When excessively heated, chlorinated solvents can **decompose**, forming highly toxic fumes such as phosgene, hydrochloric acid, and chlorine.
- With few exceptions, most of the chlorinated hydrocarbons are **non-flammable**.

Work Practices: as with all volatile hazardous materials, chlorinated solvents must always be used in a fume hood or with other local exhaust ventilation such as an approved snorkel. Inhalation of the vapors is not an acceptable work practice.

For further information, contact the EH&S Specialist at x-4899

This page intentionally left blank

Compressed Gas Cylinders

Compressed gas cylinders must be handled carefully by trained individuals. The diffusive nature of gas can result in serious hazards over large areas. Gas cylinders can be hazardous because

1) if they are mishandled, they can become “unguided missiles” with enough explosive force to go through concrete walls due to the high pressure inside the tank.
2) they often contain materials which are inherently toxic or highly flammable. For these reasons, particular care must be exercised with compressed gases.

Toxic and flammable gases have stringent and specific requirements for use and storage. UCSB has developed a Campus Toxic Gas Program, the requirements of which exceed the reach of this manual. All new installations must meet this requirements prior to use. Many of the campus labs using these gases have been and will be retrofitted to comply with current Fire Code regulations. Examples of some of the more common lab gases which fall under the provisions of this program include: fluorine, ammonia, diborane, ethylene oxide, nitric oxide, nickel carbonyl, phosgene and silane. Call the EH&S Lab Safety Specialist at x4899 for additional details.

TRANSPORT

- When transporting compressed gases or cryogens on elevators use service or freight elevators when available. In addition, when transporting cryogens by elevator:

o Post a sign reading “DO NOT ENTER – GAS TRANSPORT” to exclude passengers.

o When possible, have someone send the elevator up while another person waits on the receiving floor to take the cylinder out of the elevator. If this is not possible, another plan should be devised to ensure that the cylinder is taken out of the elevator once it reaches the desired floor.

- Disconnect regulators and other apparatus prior to transport.
- Always replace the valve cap before transporting cylinders.
- Cylinders must always be transported using a hand truck or cart designed for that purpose Transport cylinders upright.
- Do not move a cylinder by rolling, dragging or walking it across the floor. Never leave a cylinder free-standing.
- Never drop cylinders or bang them against each other or another object.

Leaks

- If the material in the tank is **toxic or flammable** and you suspect a leak, get everyone out of the area and report it to EH&S at x3194 and Dispatch at 9-911.

Storage

- All cylinders must be secured upright with **chains and brackets** bolted to a solid structural member. Chains should be 3/16 inch welded link or equivalent. Two chains must be used to secure each cylinder at a point two-thirds up and 1/3 below the cylinders height. C-clamp bench attachments and fiber/web straps are not acceptable because they are not seismically sound. Any variations of these requirements must be approved by EH&S. (Campus Policy 5445)

- Keep cylinders away from heat and sources of ignition. Do not place cylinder where contact with any electrical circuit can occur. Protect cylinders from weather extremes, dampness and direct sunlight.

- Inspect cylinders and delivery equipment routinely for signs of wear, corrosion, or damage.

- All cylinders must be clearly labeled as to their contents — do not use unlabeled cylinders and do not rely on color coding for identification.

- Understand that "Empty" implies "end of service" and as such, the cylinder may still have greater than 25 psig of pressure remaining.

Use

- Gas delivery systems involving toxic gases must be authorized by EH&S prior to installation and operation.

- Use **regulators** designed for a specific gas. (Consult your gas vendor or catalog for proper regulator **compressed gas association (CGA) number** (on nut) for use with corresponding compressed gas cylinder. Do not use any adapter between cylinders and regulators.

- Post **signs** in laboratory area when using corrosive, toxic or flammable gases. The door placard system maintained by EH&S on the campus may be used for this.

- Never modify, adapt, force or lubricate safety devices, cylinder valve or regulator.

- Do not allow grease or oil to come into contact with **oxygen** cylinder valves, regulators, gauges or fittings. An explosion or fire can result. Oxygen cylinders and apparatus must be handled with clean hands and tools. Remember that oxygen supports and greatly accelerates combustion.

- Never force a gas cylinder valve — if it cannot be opened by the wheel or small wrench provided, the cylinder should be returned.

- When opening cylinder valve, do not hold regulator. Stand with valve between you and regulator. Open cylinder valves slowly, directed away from your face.

- Release a compressed gas gently to avoid build-up of static charge which could ignite a combustible gas.

- Special precautions are necessary for acetylene usage. Note that **acetylene** can form explosive compounds in contact with copper or brass. Consult the vendor or manufacturer for proper operating equipment and procedures.

- **Do not extinguish a flame** involving a highly combustible gas until source of gas has been shut off. Re-ignition can cause an explosion.

Disposal

- Empty cylinders should be labeled "EMPTY" or "MT. Always leave at least 25 psi minimum pressure in all "EMPTY" cylinders to prevent contamination and the formation of explosive mixtures.

- Return damaged or corroded cylinders and cylinders with a test date **more than five years** old stamped on the shoulder to the vendor. Some gas cylinders should be disposed or returned at shorter intervals (e.g., **corrosives** should be disposed or returned every six months since they readily attack the cylinder fittings).

For further information, contact the EH&S Laboratory Safety Specialist at x-4899

This page intentionally left blank

LABORATORY SAFETY FACT SHEET #13

Cryogens

Examples: Liquid oxygen, liquid nitrogen, liquid helium, dry ice

Hazard Properties

- These materials are extremely cold (-100°C to -270°C) and, upon contact, can instantly freeze other materials. Serious tissue damage may occur upon exposure.
- Evaporating liquid nitrogen will displace the air within a non-ventilated space possibly leading to **suffocation**. Generally, labs have adequate ventilation to prevent this.
- Be aware of **ice that can plug or disable pressure-relief devices**. Ensure adequate pressure-relief mechanisms are functional, i.e., never use tight-fitting stoppers or closures without pressure-relief devices.

Practices

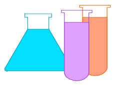
- Do not move an **over-pressurized container**. Evacuate and seal area, call EH&S (x3194) or dial 9-911.
- Avoid trapping cryogenic liquids between closed sections of an apparatus.
- **Dewar flasks** or other glassware devices should be taped on the outside or provided with shatterproof protection to minimize flying glass particles in case of implosion. Dewar flasks should be vented with a bored or notched stopper.
- Cool cryogenic containers slowly to reduce thermal shock and flashing of the material.
- Cryogen handlers should be protected by a **face shield or safety goggles, lab coat or apron and gloves or mitts.**
- When utilizing cold baths with solvents, use in a hood with a catch pan. Be aware of increased fire hazard. Be prepared for **vigorous solvent boiling** upon initial addition of solvent.
- Avoid **condensing oxygen** (blue in color) and/or contact with organic material when using liquid nitrogen. Flush cold traps with nitrogen or keep under vacuum to avoid condensation of oxygen from air within the trap. Condensed oxygen when contacted with organic materials can cause a powerful explosion.
- **Liquid helium** requires approved handling techniques and equipment due to over-pressurization hazards and icing.

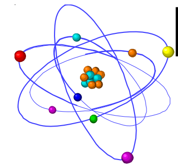
Freezing and Thawing Specimens

Cryogenic ampules can be very dangerous if they have not been properly sealed, exploding violently after removal from liquid nitrogen storage. Cells and virus stocks should be stored in sealed ampules and not in screw cap glass vials. Screw cap glass vials are permeable to liquid nitrogen (approximately 50% of the time) and therefore represent a source of contamination in the storage tank. Plastic screw cap ampules also leak and must be used with a heat sealed sleeve. Upon thawing, sealed glass vials may explode, producing an aerosol of glass and cell debris. If freezing manually, place ampules in the bottom of a beaker, cover with methanol and a dye, e.g., methylene blue, and transfer the entire beaker from refrigerator to freezer. The methanol provides even freezing and the dye will penetrate imperfectly sealed vials permitting their identification and elimination. When thawing cells, a lab coat, face guard and gloves must be worn. Ampules to be thawed should be dropped into a plastic beaker containing 70% ethanol at 37°C within a spongy bucket and covered immediately. The volatility of many of the solvents used require the use of a ventilated enclosure for vapor capture.

For further information, contact the EH&S Laboratory Safety Specialist at x-4899

LABORATORY SAFETY FACT SHEET #27





Dichloromethane
(also known as methylene chloride; CH_2Cl_2)

Exposure to dichloromethane (DM) – also known as methylene chloride - puts you at increased risk of developing cancer, adverse effects to the heart, central nervous system, liver and skin/eye irritation. Exposure may occur readily through inhalation or by skin absorption**.**

DM is one of few chemicals that has a **specific regulatory standard** written to protect workers. *Cal-OSHA Permissible Exposure Limits* for DM (see below) are low and violations of the standard can result in fines. To remain below the DM PEL, workers must always **work in a fume hood, glove box or with sealed containers** and in conjunction with adequate personal protective equipment. It is the **responsibility of the lab supervisor/PI** to ensure that all legally-required protections are in place and understood by their workers. Contact EH&S if your lab can not meet these requirements.

Exposure Hazards of Dichloromethane

Long-Term Effects of Exposure (Carcinogenicity)
Animal studies and the occurrence of disease in human work forces show a linkage between DM exposure and cancer. DM is listed as a **suspected human carcinogen** by the *International Agency on Research of Cancer* and the *National Toxicology Program*.

Short-Term Effects of Exposure

- *Inhalation* - DM is highly volatile and inhalation is therefore a major route of exposure. It can **irritate** the nose, throat and lungs. It also has an **anesthetic or narcotic effect**, causing people to feel intoxicated if overexposed. Higher exposures can cause a build-up of fluid in the lungs. A concentration of 50,000 ppm is immediately dangerous to life and health from asphyxiation.

- *Skin contact* - may irritate and burn. Can cause **dermatitis** (chapping, drying, rashes) on repeated contact with skin. May be **absorbed** through intact skin and readily passes through the blood-brain barrier to exert effects on the nervous system.

- *Eye contact* - can cause injuries ranging from transient discomfort and irritation to severe irritation with high exposures.

Cal-OSHA Legal Limits for Exposure

- *Permissible Exposure Limit (inhalation):* 25 ppm (8 hr time weighted average)
- *Short-term Exposure Limit (inhalation):* 125 ppm (15 minutes)
- *Action Level (inhalation): 12.5 ppm (more than 30 days a year)*

If EH&S, believes your exposure to DM may exceed these levels, UCSB must monitor your exposure level. If monitoring confirms that your exposure is above-limits, then a medical surveillance program must be made available to you at no cost, and/or your exposure must be reduced/eliminated.

Controlling Exposures

Engineering Controls
DM should *never* be used without adequate ventilation. It should always be used in a properly functioning **fume hood, glove box or in a sealed system**.

Protective Equipment and Clothing

- *Gloves* – the most common gloves found in campus labs/storerooms (nitrile, neoprene and latex) are **not recommended** for use with DM due to the ease with which it permeates through the glove material. The recommended gloves are "Silver Shield", polyvinyl alcohol, Viton, or "Barrier" (available from vendors like Fisher Scientific). Some of these gloves have poor dexterity characteristics, but their utility can be increased by wearing a more dexterous glove over the inner glove.

- *Eyewear* - safety glasses or goggles should be worn as with any chemical

- *Respirator* – if a fume hood is available then a respirator is not needed. If a respirator is needed for special circumstances, prior to using one, you must first contact EH&S (x-8787) to enter the UCSB Respiratory Protection Program to satisfy current Cal-OSHA requirements.

Other Requirements

Material Safety Data Sheets (MSDS) - Per Cal-OSHA, chemical-users users must know what MSDS are, their relevance to health and safety and how to readily access them. These issues are all covered in the *EH&S Lab Safety Orientation*. Regular users of DM should have a hard copy MSDS available - see the EH&S website for electronic access. The MSDS will cover the issues above and many others (e.g., flammability, spill clean-up, etc.).

Chemical Hygiene Plan – Per Cal-OSHA, dichloromethane is considered a **Particularly Hazardous Substance.** Therefore, its safe use must be addressed in your laboratory's written Chemical Hygiene Plan (CHP). Since many safety issues are addressed generically in this document, it can be used as a resource in developing your CHP. Lab supervisors/PIs should contact EH&S at x-4899 if you need an orientation to this requirement.

LABORATORY SAFETY FACT SHEET #12

Guidelines for Safe Use of Electrophoresis Equipment

Electrophoresis units can present several types of hazards including electrical, chemical, and sometimes radiological. The general information presented here however, should not be viewed as a substitute for the specific owner's manual and instructions provided by the manufacturer. Below is a link to an accompanying **checklist** to assist researchers in safely operating electrophoresis units.

Proper Equipment Set-Up

Place electrophoresis units and their power supplies so that the on/off switch is easy to reach and the power-indicator lights are easily seen. Locate the equipment where it will not be easy to knock over or trip on.

Because electrophoresis work involves handling conductive liquids around electricity, power supplies should be protected by ground fault circuit interrupters (GFCIs). GFCIs act as very sensitive circuit breakers and, in the event of a short circuit, will stop the power before it can hurt a person. You can identify GFCIs by their "test" and "reset" buttons. They are found on some outlets or breaker boxes. An adapter type, which plugs into a standard outlet and does not require installation by an electrician, can be purchased at local hardware stores at prices starting at $20.

Addressing Electrical Hazards

Electrophoresis units use very high voltage (approximately 2000 volts) and potentially hazardous current (80 milliamps or more). This high power output has the potential to cause a fatal electrical shock if not properly handled.

Routinely inspect electrophoresis units and their power supplies to ensure that they are working properly. Power supplies should be inspected to ensure that all switches and lights are in proper working condition, that power cords and leads are undamaged and properly insulated, and that "Danger—High Voltage" warning signs are in place on the power supply and buffer tanks.

Inspect the buffer tanks for cracks or leaks, exposed connectors, or missing covers. If your units have such hazards, replace the units with new models that have these safety features built in, or contact EH&S for information on individuals approved to perform retrofitting.

Training and Work Procedures

Principal investigators are responsible for providing instruction on the safe use of electrophoresis units to those in the laboratory who work with them. The instruction should cover the operating procedures written by the manufacturer or laboratory, as well as the associated hazards, the correct personal protective equipment, and applicable emergency procedures. As with all safety training, this instruction should be documented.

Employees must wear all appropriate personal protective equipment when working with electrophoresis units, including lab coats, gloves, and eye protection.

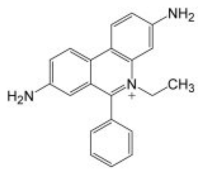
Do not leave electrophoresis units unattended for long periods of time since unauthorized persons may accidentally come in contact with the unit, or the buffer tank liquid may evaporate, risking a fire.

Labs that perform electrophoresis work during off-hours should consider using a "buddy system" to ensure that emergency services can be notified if someone is injured or exposed. It is also recommended that laboratory personnel be trained in CPR and in First Aid.

An **Electrophoresis Safety Checklist** is available via the UC Berkeley website at:

https://www.ehs.berkeley.edu/sites/default/files/lines-of-services/workplace-safety/04electro.pdf

The checklist, can be used to determine whether the electrophoresis units and their power supplies are in safe working condition. The equipment should not be used until all hazards have been safeguarded.



Ethidium Bromide Treatment and Disposal

Ethidium bromide is a commonly used stain for identifying nucleic acids in electrophoresis gels. It is known to be toxic and mutagenic and may be fatal if swallowed and harmful if inhaled or absorbed through the skin.

Before working with a chemical, know all of the potential hazards and safety precautions by reviewing the material safety data sheet (MSDS). Always wear personal protective equipment including gloves, goggles and a lab coat when working with ethidium bromide. Also, protect yourself from any UV sources that you may use when visually inspecting for ethidium bromide.

Waste Management Procedures

Gels, filters, and other solids containing ethidium bromide *must* be managed as a hazardous chemical waste and disposed of through EH&S. The waste must be double bagged, labeled with an EH&S hazardous waste label and placed in secondary containment. Do not use a biohazardous waste bag to package ethidium bromide waste.

Ethidium bromide solutions *cannot* be disposed of down the sanitary sewer. Ethidium bromide solutions must be treated as part of the experimental protocol or managed as a hazardous chemical waste and disposed of through EH&S.

Charcoal filtration treatment is a simple and effective method for removing ethidium bromide from electrophoresis buffers through a bed of activated charcoal. Prior to drain disposal of the filtered non-hazardous solution, check for fluorescence by using a UV light to ensure complete removal of the ethidium bromide. You can build your own filter or purchase one. When the filter is saturated, the charcoal must be managed as a hazardous chemical waste and disposed of through EH&S.

Charcoal filtration treatment of ethidium bromide solutions must follow the steps outlined in AB966 Benchtop Treatment:

- The laboratory hazardous waste treated is less than 5 gallons or 18 kg per batch whichever is greater.
- The laboratory hazardous waste is treated at the point of generation.
- Treatment is conducted within 10 calendar days of accumulation.
- The person performing the treatment has knowledge of the laboratory hazardous waste being treated, including knowledge of the procedure that generated the waste, and has received hazardous waste training.

Please note that oxidation of ethidium bromide with bleach is not an acceptable destruction technique and must not be used.

Alternatives To Ethidium Bromide

There are less hazardous and environmentally friendly alternatives to ethidium bromide. For more information visit the websites of the products listed below.

Company	Product	Website
Invitrogen	SYBR Safe	http://probes.invitrogen.com/products/sybrsafe/
Biotium	GelRed / GelGreen	http://www.biotium.com/
AMRESCO	EZ Vision DNA Dye	http://www.amresco-inc.com/

This page intentionally left blank

LABORATORY SAFETY FACT SHEET #9

Formaldehyde and Formalin

Long-term exposure to formaldehyde (HCHO) puts you at increased risk of developing cancer. Short-term exposure – even at very low concentrations - can cause severe irritation to the eyes, skin and respiratory tract. Formaldehyde is a highly toxic and flammable gas with a strong pungent odor. However, it is most commonly used as an aqueous solution (**formalin**) which often also contains some methanol. It is commonly used in tissue fixing and preservation, disinfection and as an organic chemical reagent.

It is one of the few chemicals with a **specific regulatory standard** written to protect workers. Cal-OSHA permissible exposures levels for formaldehyde are very low and violations of the standard can result in heavy fines[1]. It is the responsibility of the **lab supervisor/PI** to ensure that all legally-required protections are in place and understood by their workers. EH&S periodically evaluates potential formaldehyde exposures for campus labs.

Exposure Hazards of Formaldehyde

Short-Term Effects of Exposure

- *Inhalation* – formaldehyde is highly volatile and inhalation is therefore a major route of exposure. Above 0.1ppm it can **irritate the nose, throat and lungs**, but its odor threshold is higher – about 1 ppm. Therefore, lack of odor cannot be used as an indicator of safety. Above 25 ppm it can cause severe injury, including pulmonary edema (water in the lungs).

- *Skin contact* – causes skin irritation and in some individuals an allergic dermatitis (rash)

- *Eye contact* – eyes are particularly vulnerable to formaldehyde and above about 2 ppm, it is quickly irritating. Above 20 ppm can cause permanent clouding of the cornea.

Long-Term Effects of Exposure

Formaldehyde has been shown to cause **cancer** in lab animals and can cause cancer in humans. It is listed as a **known human carcinogen** by the *International Agency on Research of Cancer* and the *National Toxicology Program*.

Cal-OSHA Legal Limits for Exposure

Permissible Exposure Limit (inhalation): 0.75 ppm (8 hr time-weighted average)
Short-term Exposure Limit (inhalation): 2 ppm (15 minutes)
Action Level (inhalation): 0.5 ppm
If EH&S suspects your exposure to formaldehyde may exceed these levels, UCSB must monitor your exposure level. If you work with formaldehyde outside of a fume hood, or glove box it is likely that your exposure is above-limits. If monitoring confirms that your exposure is above-limits, then a medical surveillance program must be made available to you at no cost.

Controlling Exposures

Engineering Controls
Given its volatility and toxicity, formaldehyde **should only be used in a fume hood or glove box.** Breathing HCHO fumes is not acceptable.

Protective Clothing and Equipment

- *Skin protection* – gloves must be worn whenever formalin, or tissues preserved/fixed with formalin, are handled. Medium or heavyweight **nitrile, neoprene, natural rubber, or PVC gloves** should be worn when handling. Disposable (exam) nitrile gloves may be used when handling dilute concentrations (10% or less). Use of a lab coat is strongly recommended.

- *Eyewear* – given the severe effect of formaldehyde on the eye, normal safety glasses are not recommended for procedures with splash potential. Instead, wear chemical goggles or a face shield when handling formaldehyde to minimize the risk of even a small splash or vapor exposure to the eyes.

- *Respirator* – if a fume hood is used, then a respirator is not needed. If a respirator is needed for special circumstances, you must first contact EH&S (x-8787) to enter the UCSB Respiratory Protection Program to satisfy OSHA requirements.

Other Issues

Material Safety Data Sheets (MSDS) - Per Cal-OSHA, formaldehyde users must know what MSDS are, their relevance to health and safety and how to readily access them. These issues are all covered in the EH&S Lab Safety Orientation. Regular users of formaldehyde should have a hard copy MSDS available - see the EH&S website for electronic MSDS access.

Chemical Hygiene Plan – Per Cal-OSHA, formaldehyde/formalin is considered a **Particularly Hazardous Substance.** Therefore, its safe use must be addressed in a laboratory's written Chemical Hygiene Plan (CHP). Since many safety issues are addressed generically in this document, it can be used as a resource in developing your CHP. Lab supervisors/PIs should contact EH&S at x-4899 if you need an orientation to this requirement.

Flammability - Formalin is not a significant fire risk. Formaldehyde gas is highly flammable.

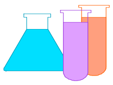
Chemical Compatibility - See Material Safety Data Sheet

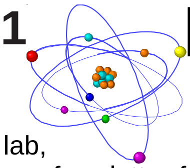
First Aid - For skin and eye contact, use the lab emergency shower/eyewash to immediately flush with plenty of water for at least 15 minutes. Remove contaminated clothing. For serious inhalations, immediately move the person to fresh air and call 9-911 for immediate medical attention.

Spill, Leak and Disposal - Place leaking containers in a fume hood. If it can be done safely, clean-up small spills with absorbent material – available in many buildings "spill closet". For larger spills, leave the area and contact EH&S at x-3194. Like other chemical wastes, all formaldehyde wastes should be disposed of through EH&S. Sink disposal is not legal.

Footnotes:
1. Example: Columbia University was fined $77,000 in 1999 for violations of the OSHA formaldehyde standard.

LABORATORY SAFETY FACT SHEET #31





HOUSEKEEPING AND CLUTTER IN THE LABORATORY

Fire, property loss, and injury can result from excessive clutter and poor housekeeping. Good housekeeping can also facilitate good relations within the lab, improve lab technique and make the lab a place you're proud to bring visitors into. The route to a safer, clutter-free lab is to make it a group effort. All lab members should make it part of their daily routine. Below are a few simple steps that can be included in your daily work practices.

WHAT TO LOOK FOR IN YOUR LAB:

1. Chemicals

- ***Keep chemicals stored in the appropriate cabinets or designated storage rooms when not in use (NOT IN FUME HOODS).*** Only obtain an amount to keep your test or research going, like a one day/week supply. This will free up lab bench space and, if you do have a spill it will minimize the amount of chemical released.
- Put away all reagents, samples, and personal materials.
- ***Keep the lids on chemical containers.*** This sounds obvious but it will effectively reduce the possibility of a spill and reduce any fumes released into your lab and it's the law.
- ***Label all containers.*** Make sure there are no unidentified containers; reagents, samples, drying papers with sample, or crucibles/boats with samples. Label all material by chemical name (Not just initials)

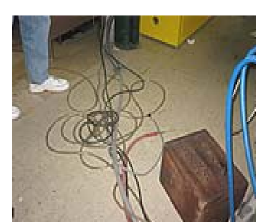
2. Cleaning Your Lab

- Properly dispose of old or unwanted chemicals or any unnecessary items.
- Damp wipe all benchtops until clean and in particular areas near weighing stations. Place absorbent paper near weighing stations or any where else necessary.
- Clean up inside fume hoods.
- Look inside all cabinets for leftover waste and any storage hazards.
- Dispose broken glass trash and "sharps" bins into dumpster outside the building.
- Recycle paper and cardboard properly where it will be promptly removed.
- Unused or spare equipment should be stored in a designated storage room/area.
- Equipment or furniture should not block walkways, electrical panels, or emergency eyewash or showers.
- Check emergency egress path is maintained (minimum exit pathway in rooms is 28 inches)
- Don't move your housekeeping problem into the hallway or some other undesirable/illegal location.

3. How cluttered are your lab benches and hoods?

- ***Keep lab benches and hoods uncluttered as much as possible.*** This may seem impossible when conducting complicated tests or have numerous test samples, but continually remind yourself to keep things organized.
- ***Keep containers and equipment away from the edge of benches.*** Are you reaching over bottles, cultures, etc. to get to something? Chances are you're about to knock something on the floor.
- What about the shelves above your desk or lab bench? ***Keep shelving as orderly as possible.*** Be realistic about how much equipment and supplies one needs to store long term.

4. Other



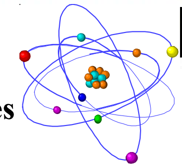
- Implement a group clean-up session weekly, monthly, etc. Verify the lab(s) are clean, organized and anything else required to make the lab look professional.
- Check for trip and slip hazards (e.g. oil leaks from pumps, electrical cords or hoses across walking path)

This page intentionally left blank

Rev. 4/10

LABORATORY SAFETY FACT SHEET #36

Engineered Nanomaterials: Guidelines for Safe Research Practices



Introduction

This document provides environmental, health and safety information to researchers working with engineered nanoparticles, and should be formally incorporated as a Standard Operating Procedure into each laboratory's Chemical Hygiene Plan binder (Cal-OSHA requirement). Researchers are encouraged to customize this document as appropriate to their operation. Given the evolving knowledge base regarding health effects of nanoparticles, this fact sheet may be updated.

Nanoparticles are particles that have at least one dimension between 1-100 nanometers. Particles in this size range have always been present in Earth's air. Nanoparticles may be naturally occurring (such as in volcanic ash), produced as unintentional byproducts (such as in auto emissions) or intentionally created or "engineered." These very small particles often possess radically different properties than larger particles of the same composition, making them of interest to researchers and of potential benefit to society. This fact sheet focuses on lab practices researchers should follow to protect themselves from the hazards of engineered nanoparticles.

Nanoparticles can be spheres, rods, tubes, and other geometric shapes. The small particles may be bound to surfaces or substrates, put into solution or suspension, attached to a polymer, or in a few cases handled as a dry powder. Various nanoparticles can be created in the laboratory under experimental procedures, and some can be purchased from commercial vendors. In most research, the amount of material used is small, generally less than a gram.

Only limited information is currently available on the toxicity of a few types of nanoparticles. It is believed that some engineered nanoparticles may present health effects following exposure, based in part on air pollution studies that show smaller particles get deep into the lungs and can cause human illness. However, laboratory research most commonly involves handling nanoparticles in liquid solutions or other forms that do not become easily airborne, and even free-formed nanoparticles tend to agglomerate to a larger size.

When research involves work with engineered nanoparticles for which no toxicity data is yet available, it is prudent to assume the nanoparticles may be toxic, and to handle the nanoparticles using the laboratory safety techniques outlined below.

Potential Routes of Occupational Exposure to Researchers

There are four possible routes of workplace exposure to nanoparticles: inhalation, ingestion, skin absorption, and injection.

<u>Inhalation</u>. Respiratory absorption of airborne nanoparticles may occur through the mucosal lining of the trachea or bronchioles, or the alveolus of the lungs. Because of their tiny size, certain nanoparticles appear to penetrate deep into the lungs and may translocate to other organs following pathways not demonstrated in studies with larger particles. Thus, whenever possible, nanoparticles are to be handled in a form that is not easily made airborne, such as in solution or on a substrate.

Skin absorption. In some cases nanoparticles have been shown to migrate through skin and be circulated in the body. If the particle is carcinogenic or allergenic, even tiny quantities may be biologically significant. Skin contact can occur during the handling of liquid suspensions of nanoparticles or dry powders. Skin absorption is much less likely for solid bound or matrixed nanomaterials.

Ingestion. As with any material, ingestion can occur if good hygiene practices are not followed. Once ingested, some types of nanoparticles might be absorbed and transported within the body by the circulatory system.

Injection. Exposure by accidental injection (skin puncture) is also a potential route of exposure, especially when working with animals or needles.

Laboratory Safety Guidelines for Handling Engineered Nanoparticles
The current practices for working with engineered nanoparticles safely are essentially the same as one would use when working with any research chemical of unknown toxicity.

1. Wear double gloves (preferably nitrile gloves), safety glasses or goggles, and appropriate protective clothing. The gloves will help prevent skin exposure and reduce the chances of accidental injection by needle, or animal bite. Outer gloves should always be removed inside the hood or under the influence of local exhaust ventilation and placed into a sealed bag. This will prevent the particles from becoming airborne. Place Tacki-Mat at the exit to reduce the likelihood of spreading nanoparticles.

2. All personnel participating in research involving nanoscale materials need to be briefed on the potential hazards of the research activity, as well as on proper techniques for handling nanoparticles. The contents of this Fact Sheet can serve as a useful component of this training. As with all safety training, written records need to be maintained to indicate who has been trained on this topic.

3. To prevent ingestion, eating and drinking and chewing gum are not allowed in laboratories, except perhaps in designated areas.

4. When purchasing commercially available nanoscale materials, be sure to obtain the Material Safety Data Sheet (MSDS) and to review the information in the MSDS with all persons who will be working with the material. Note, however, that given the lack of extensive data on nanoparticles, the information on an MSDS may be more descriptive of the properties of the bulk material.

5. In some cases, the manufacture of nanomaterials involves the use of chemicals that are known to be hazardous. Be sure to consider the hazards of the precursor materials when evaluating the process hazard or final product. Users of any chemicals should make themselves familiar with the known chemical hazards by reading the MSDS or other hazard literature.

6. To minimize airborne release of engineered nanoparticles to the environment, nanoparticles are to be handled in solutions, or attached to substrates so that dry material is not released. Where this is not possible, nanoscale materials should be handled with engineering controls such as a HEPA-filtered local capture hood or glove box. An example of a HEPA-filtered hood specifically for nanomaterials is shown. If neither is available, work should be performed inside a laboratory fume hood. HEPA-filtered local capture systems should be located as close to the possible source of nanoparticles as possible, and the installation must be properly engineered to maintain adequate ventilation capture.

Example of HEPA-filtered hood at UCSB specifically for nanomaterial use

7. Use fume exhaust hoods to expel any nanoparticles from tube furnaces or chemical reaction vessels. Do not exhaust aerosols containing engineered nanoparticles inside buildings.

8. If you must work outside of a ventilated area with nanomaterials that could become airborne, wear a respirator with NIOSH-approved filters that are rated as N-, R- or P-100 (HEPA). EH&S will work with researchers to provide the most appropriate type of respirator.

9. Lab equipment and exhaust systems used with nanoscale materials should be wet wiped and HEPA vacuumed prior to repair, disposal, or reuse. Construction/maintenance crews should contact EH&S for assistance.

10. Spills of engineered nanoparticles are to be cleaned up right away.
    a. The person cleaning up should wear double nitrile gloves and either vacuum up the area with a HEPA-filtered vacuum or wet wipe the area with towels, or combination of the two.
    b. For spills that might result in airborne nanoparticles, proper respiratory protection should be worn (see item 8 above). For assistance with cleaning up any chemical spill contact EH&S.
    c. Do not brush or sweep spilled/dried nanoparticles.
    d. Place Tacki-Mat at the exit to reduce the likelihood of spreading nanoparticles.

11. Work surfaces should be wet-wiped regularly – daily is recommended. Because many engineered nanoparticles are not visible to the naked eye, surface contamination may not be obvious. Alternatively, disposable bench paper can be used.

12. All waste nanoparticles should be treated as unwanted hazardous "toxic" materials unless they are known to be non-hazardous. Dispose of and transport waste nanoparticles in solution according to hazardous waste procedures for the solvent. If you have questions on how to dispose a specific nanoparticle waste, call EH&S for more information.

For more information on Health and Safety of Nanotechnology visit the following web sites:

National Institute of Occupational Safety and Health
(http://www.cdc.gov/niosh/topics/nanotech/)

National Nanotechnology Initiative (http://www.nano.gov/)

EPA (http://www.epa.gov/oppt/nano/nano-facts.htm)

Woodrow Wilson International Center for Scholars (http://nanotechproject.org/)

This page intentionally left blank

LABORATORY SAFETY FACT SHEET #17

Peroxides and Distillations

Extractions

Before pouring a liquid into a separatory funnel, make sure the stopcock is closed and has been lubricated. Use a stirring rod to direct the flow of the liquid being poured. Keep a beaker under the funnel in the event the stopcock comes open unexpectedly. Do not attempt to extract a solution until it is cooler than the boiling point of the extractant. When a volatile solvent is used, the unstoppered separatory funnel should first be swirled to allow some mixing. Shake with a swirl holding the stopper in place and immediately open the stopcock. Repeat until it is evident that there is no excessive pressure. Swirl again as the funnel is racked, immediately remove the stopper, and separate when appropriate.

Distillations

Ethers must never be distilled unless known to be free of peroxides. Most ethers, including cyclic ethers, form **dangerously explosive peroxides** on exposure to air and light.

What are organic peroxides?

Organic peroxides are a class of compounds that have unusual stability problems that make them among the most hazardous substances found in the laboratory. The lack of stability is due to the presence of an oxidation and reduction center within the same molecule.

R-O-O-R

where, R = organic side chains and O-O = Peroxo bridge

As a class, organic peroxides are considered to be powerful explosives and are sensitive to heat, friction, impact, light, as well as to strong oxidizing and reducing agents. Peroxide-formers react with oxygen even at low concentrations to form peroxy compounds. The instability of the molecule (R-O-O-R) can cause auto-decomposition simply by bumping or jarring the container, addition of heat, light, or opening the cap. **The risk associated with the peroxide increases if the peroxide crystallizes or becomes concentrated by evaporation or distillation. Peroxide crystals may form on the container plug or the threads of the cap and detonate as a result of twisting the lid.**

Classes of Peroxide Formers

Aldehydes

Ethers - especially cyclic ethers and those containing primary and secondary alcohol groups

Compounds containing benzylic hydrogen atoms (particularly if the hydrogens are on tertiary carbon atoms)

Compounds containing the allylic structure, including most alkenes.

Vinyl and vinylidene compounds.

Preventing Formation of Organic Peroxides
No single method of inhibition of peroxide formation is suitable for all peroxide formers. Use of different inhibitors is discussed in the literature (0.001 to 0.01% hydroquinone, 4-tert-butylcatechol (TBC) or 2,6-di-tert-butyl-p-methylphenol (BHT)); however, limiting size of container and regular testing (every 3 months) and disposal is probably more effective (and certainly easier) for managing peroxide formation.

Ethers and other organic peroxide formers should be stored in cans, amber bottles, or other opaque containers, and ideally under a blanket of inert gas. It is preferable to use small containers that can be completely emptied rather than take small amounts from a large container over time. Containers of ether and other peroxide-forming chemicals should be marked with the date they are opened, and marked with the date of required disposal.

Common laboratory chemicals that form peroxides during storage include:

Acetal	Decalin	Dimethyl ether	Methylcyclopentane	Tetralin
Butadiene	Diacetylene	Divinyl acetylene	Potassium metal	Vinyl acetate
Cumene	Dicyclopentadiene	Ethyl ether	Sodium amide	Vinyl actylene
Cyclohexene	Diethylene glycol	Ethylene glycol dimethyl ether	Styrene	Vinyl choride
Cyclooctene	Diisopropyl ether	Isopropyl ether	Tetrahydrofuran	Vinyl ethers
Decahydronaphthalene	Dioxane	Methyl acetylene	Tetrahydronaphthalene	Vinylidene chloride

Storing Peroxide Formers
Mark on containers of time-sensitive materials both the date of receipt and the date the container is first opened. Time-sensitive materials should be marked with a tag to make them easily identified. No materials should be used or tested after the manufacturers' expiration date unless evidence of current stability has been obtained via direct testing prior to the expiration date.

NOTE: If material is old (> 1 year past label expiration date) then minimize handling and DO NOT OPEN OR ATTEMPT TO TEST! Call EHS (x-3293) to request special disposal for this item. Isolate the container from possible inadvertent use until picked up. If the material is very old or shows evidence of conversion to a hazardous status (i.e.,
crystalline materials in/under cap of ethers), do not move the container!

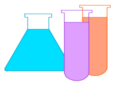
Peroxide Detection Tests
From *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*, 1995: The following tests will detect most (but not all) peroxy compounds and all hyperperoxides. Results of peroxide detection tests must be indicated on the container/tag with test date, test results/method, and initials of the authorized person conducting the test. NOTE: These tests should not be used for testing materials potentially contaminated with inorganic peroxides (i.e., potassium).

Option 1. Add 1-3 ml of the liquid to be tested to an equal volume of acetic acid, add a few drops of 5% potassium iodide (KI) solution and shake. The appearance of a yellow to brown color indicates the presence of peroxides.

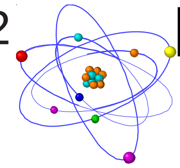
Option 2. Addition of 1 ml of a freshly prepared 10% KI and 10 ml of an organic solution in a 25 ml glass cylinder should produce a yellow color if peroxides are present.

Option 3. Add 0.5 ml of the liquid to be tested to a mixture of 1 ml of 10% KI solution and 0.5 ml of dilute hydrochloric acid to which a few drops of starch solution have been added just before the test. The presence of a blue-black color within a minute indicates the presence of peroxides.

Option 4. Peroxide test strips that turn an indicative color in the presence of peroxides. Take care to follow manufacturer instructions for effective detection. In general, the strips must be air dried until the solvent evaporates and then exposed to moisture for proper operation.



LABORATORY SAFETY FACT SHEET # 32



Be Prepared for Power Failures

Extended power outages can affect the campus, or individual buildings. For updates about a power failure, contact your building coordinator (e.g. MSO), or Department Safety Rep. Listen to KCSB FM – 91.9 radio for updates. Should the campus experience an extended electrical outage, the Emergency Operations Center at the Environmental Health and Safety building will activate to manage the campus response.

Emergency Lighting and Power

Building emergency lighting provides enough illumination for a safe exit. The lighting will either be battery-powered, or run off an emergency generator. Battery-run units should last a couple of hours, but may fail sooner. Some campus buildings have emergency generators, but what is powered varies by building. They typically only power emergency exit lighting, life safety systems and laboratory exhaust. Electrical outlets in labs that are on an emergency generator are typically red in color.

Data Backup

Back up your computer files regularly so as not to lose data when the power goes off suddenly. Use an Uninterruptible Power Supply (UPS) for critical machines such as servers.

Power Failure in Laboratories

Before Power Fails

- Be sure the after-hours contact information on your lab door placard is up-to- date. Ideally, these individuals should be knowledgeable about all of the laboratory's major operations, particularly those that are hazardous/sensitive to power outages.
- Put essential equipment on emergency power circuits if available. Contact Facilities Management - they may be able to provide additional service capacity, along with a small number of portable units that may be available to keep critical operations going during power interruptions.
- Make a list of equipment that must be reset or restarted once power returns. Keep instructions for doing so in a nearby place. Hazardous processes that operate unattended should be programmed to shut down safely during a power failure and not restart automatically when power returns.
- Identify an emergency source of dry ice if you have items that must be kept cold. Refrigerators and freezers will maintain their temperature for several hours if they are not opened. **Do not use dry ice in walk-in refrigerators or other confined areas** because hazardous concentrations of carbon dioxide gas will accumulate.

While the Power is Off

- Shut down experiments that involve hazardous materials or equipment which automatically restart when power is available.
- Make sure that experiments are stable and do not create uncontrolled hazards such as dangerous vapors in a non-functioning fume hood.
- Check fume hoods. Stop any operations that may be emitting hazardous vapors. Cap all chemical containers that are safe to cap, and then close the fume hood sashes. Leave the room and contact EH&S if you notice any odors or physical symptoms.
- Check equipment on emergency power. In some cases, it may take 20 to 30 seconds for the emergency power to activate after a power failure.
- Disconnect equipment that runs unattended, and turn off unnecessary lights and equipment. This will reduce the risk of power surges and other unforeseen problems that could result when the power comes on unexpectedly.
- Check items stored in cold rooms and refrigerators. You may need to transfer vulnerable items to equipment served by emergency power.

When the Power Returns

- Reset/restart/check equipment. In particular, check that the air flow of your fume hood. Often, hoods will not automatically restart.
- If a refrigerator or freezer fails to restart, keep the door closed until it has been repaired and returns to a safe working temperature.
- Contact EH&S for assistance with any spill cleanup or disposal issues.

Other Emergency Planning Tips

Take this opportunity to review your lab and building emergency procedures before a power failure strikes. In particular, your *Department Emergency Operations Plan* will provide building-specific emergency response and evacuation information. Contact your Department Safety Rep to review. However, at minimum, every worker must know: **emergency exit routes from the building, and the locations of the following relative to their work area: building Emergency Assembly Point, nearest fire extinguishers, nearest fire alarm pull station, lab emergency shower/eyewash and first-aid kit.** If unsure, talk to your supervisor, or Department Safety Rep, or EH&S.

LABORATORY SAFETY FACT SHEET #5
Refrigerators & Freezers in Lab

Certain refrigerator/freezer units are designed for the safe storage of flammable materials, and to prevent potentially injurious explosions in your lab. These units have special protections to prevent ignition of flammable vapors. For example, the light switch, defrost feature, and thermostat inside the storage compartment have been removed or relocated outside the box. This is critical, since flammable vapors coupled with an ignition source could result in a explosion. Before purchasing a new refrigerator/freezer, or using an existing one, consider whether chemicals will be used for storage in this unit.

There are two types of refrigerator/freezer models that should be considered, depending on the type of hazardous material the unit will store.

I. FLAMMABLE MATERIAL STORAGE REFRIGERATORS/FREEZERS:

These have no internal electrical components which could trigger an explosion inside the unit. These must always be used for storage of volatile materials.

II. EXPLOSION-PROOF REFRIGERATORS/FREEZERS :

These units prevent triggering of interior or exterior explosions in a hazardous environment. Every motor and thermostat is designed to prevent arcing and possible ignition. They are used for storage of volatile materials in areas with explosive atmospheres.This model is rarely necessary in lab environments

All refrigerator/freezer purchases and modifications on campus **must be pre-approved** by EH&S at X8243. In addition, all approved refrigerator/freezer units storing flammable materials must be labeled with signage reading, “Approved For Chemical Storage, No Food Storage”. All refrigerator/freezer units in labs, which are not approved for storage of flammable materials must be affixed with signage reading, “Explosion Hazard”. Contact EH&S to receive your free label(s).

This picture shows a UCI lab refrigerator which exploded when chemicals were inappropiately stored in a unit which was not designed for flammables storage.

For further information contact EH&S Laboratory Safety Specialist at X4899

This page intentionally left blank

Laboratory Safety Fact Sheet #1

Nonstructural Seismic Hazard Reduction Policies

Earthquakes have occurred and will continue to occur in the Santa Barbara area. This is of particular concern in UCSB laboratories where the presence of hazardous materials, compressed gases, high voltage sources, etc., would pose serious hazards to individuals and buildings in a quake. In addition, the presence of expensive, difficult to replace lab equipment makes the need for evaluating the seismic anchoring needs of your lab critical.

Campus policies:

- All furnishings and equipment over 48 inches in height must be fastened to a wall or floor in a manner to prevent falling in an earthquake.

- Storage of large, heavy items must be kept below head level.

- All compressed gas cylinders must be secured individually to a solid structural member with 3/16 inch welded chain or equivalent bracing. At least one chain must be used to secure each cylinder at a point two-thirds up the cylinder's height. C-clamp bench attachments and fiber/web strap attachments will not be allowed. Any variations of these requirements must be approved by Environmental Health & Safety.

- Chemical storage shelving must have shelf lips or other restraining devices (e.g. wire or bungee cord along edge) installed to prevent chemicals from falling.

- To prevent accidental mixing of chemicals that could result in a fire, explosion or toxic release, incompatible chemicals must be segregated into separate, labeled areas or into separate rigid secondary containment such as plastic tubs. For more specific information on the classification and storage of particular chemicals consult the *UCSB Chemical Hygiene Plan* or contact EH&S at x-4899.

Recommended practices:

- While not a safety issue, there are often expensive pieces of lab equipment, e.g. electronics, that you may wish to seismically anchor. UCSB Central Stores carries products that work well for securing these items.

- Based on earthquake experiences at Cal State Northridge, UCLA and UCSC it is recommended that researchers maintain extra copies of irreplaceable files such as research data in a separate location.

Responsibility: The responsibility for compliance and funding of these policies rests with the department Chair or department head. Lab supervisors are responsible for identifying and implementing areas where the above policies apply in their labs. Environmental Health & Safety will act in an advisory capacity.

References:

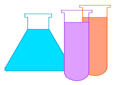
University Policy on Seismic Safety, rev. 5/2/94
University Policy on Nonstructural Seismic Hazard Reduction, Policy 5445, rev. 6/1/95

For further information contact the EH&Sx-4899

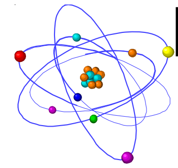
Rev. 7/97

This page intentionally left blank

LABORATORY SAFETY FACT SHEET #25



TIME-SENSITIVE CHEMICALS



Some chemicals can undergo slow reaction while in storage to form other materials which are inherently unstable and prone to violent decomposition, i.e. time-sensitive chemicals. An example of this occurred at UCSB in 7/05 when an old lecture bottle cylinder of anhydrous hydrogen fluoride spontaneous exploded; fortunately no one was injured. It is therefore important to understand what these materials are and how to properly manage them. The most commonly recognized time-sensitive chemicals include the following:

Gases: Vendors recommend that corrosive gases (acids/bases) be consumed or disposed of within 2 years. This can be due to two reasons: Some acids slowly buildup dangerous pressures of hydrogen gas due to a reaction of the corrosive with the cylinder walls; or the corrosive will attack the internal or external metal fittings of the cylinder resulting in leaks, or frozen valves. Examples:

- Hydrogen fluoride, anhydrous (hydrogen pressure buildup and cylinder corrosion)
- Hydrogen bromide, anhydrous (hydrogen pressure buildup and cylinder corrosion)
- Hydrogen sulfide, anhydrous (anecdotal reports of pressure buildup)
- Hydrogen cyanide, anhydrous (violent polymerization can occur)
- Hydrogen chloride, anhydrous (corrosion of fittings and cylinder)

Solids/Liquids: For a good overview of these hazards see the article at: http://dx.doi.org/doi:10.1016/j.chs.2004.05.017 Note that organic solvents which form **peroxides (e.g. ethers)** are the most common materials in this category and can be found in most campus labs. The other classes of materials addressed in the article are: multi-nitro compounds (e.g. picric acid); chloroform; formic acid; alkali metals; metal fulminates; and heavy metal acetylides.

It should also be noted that there is a difference between a time-sensitive chemical and a shock-sensitive chemical (not addressed here). The former can become the latter, but there are shock-sensitive chemicals that are always so and do not require time to develop. However, these will rarely be found in campus labs, except possibly in Chemistry.

MANAGEMENT OF TIME-SENSITVE CHEMICALS

For a review of good management practices, also see the article noted above. However, the most fundamental management tasks are to:

a. know what you have in stock
b. date materials that are time-sensitive
c. purge them regularly

For further information contact the EH&S Laboratory Safety Specialist at x-4899

This page intentionally left blank

Appendix B: Chemical Resistance of Common Lab Gloves

This information has been integrated into the CHP and can now be found on page 40.

This page intentionally left blank

Appendix C: MRL Emergency Operations Plan

This appendix reproduces the MRL Emergency Operations Plan (also Emergency Action Plan & Fire Prevention Plan), accessed on 3/29/23 via

http://www.mrl.ucsb.edu/mrl-emergency-operations-plan

Materials Research Laboratory
UCSB Building 615
Emergency Operations Plan
AKA Emergency Action Plan & Fire Prevention Plan
This plan is adopted by the MRL on June 17, 1998
Craig Hawker, Director

SUMMARY
In the event of a fire alarm or other emergency evacuation, all persons are to leave the MRL Building and to assemble on the sidewalk at the southwest corner of Engineering II. **See area map for location**. In the event of a major earthquake, all persons are to seek shelter in a door frame or other protected space. After the earthquake stops, and as soon as it is safe, all persons are to exit the building and to assemble on the sidewalk at the southwest corner of Engineering II. **See area map**.

MRL EMERGENCY PERSONNEL
Amanda Strom is the Hazard Communication Coordinator (HCC) for the MRL. She is also a member of the campus Emergency Response Team (ERT) and responsible for most utility and construction issues affecting the MRL Building. She can be reached at x7925 or by e-mail at **amanda@mrl.ucsb.edu**. His office is on the second floor in Room 2066F. Sara Bard is the Management Services Officer for the MRL as well as the Alternate HCC. She can be reached at x8519 or by e-mail at **joni@mrl.ucsb.edu**. Her office is located on the second floor in Room 2066E.

PREPARATIONS
The MRL shall maintain an Emergency Response Kit and it shall be stored in the 2nd floor kitchen (Rm 2042). This kit shall contain at least an AM-FM portable radio, a flashlight, extra batteries, and a first aid kit. First aid kits shall be kept in the 2nd floor kitchen (Rm 2042), 3rd floor kitchen (Rm 3026), TEMPO 1023, and vestibule between Polymer lab and TEMPO (Rm 1137). Chemical spill cleanup kits shall be kept in the vestibule between Polymer lab and TEMPO (Rm 1137), and 1278 (contact Amanda Strom for access). Laboratories, offices, and storage areas are to be kept in a safe fashion and in compliance with all environmental and safety regulations and good practice. All tall furniture is to be secured so that it will not fall over in an earthquake. All chemicals are to be stored in an appropriate and compatible manner. Chemical bottles are to be secured against falling during an earthquake. Researchers and other individuals are strongly encouraged to have copies of valuable and irreplaceable information stored away from campus, so that it is both safe and accessible if a building is temporarily or permanently closed. At least one member of the MRL technical staff should be a member of the campus Emergency Response Team (ERT). This person will receive training in

hazardous materials, drill with the campus team, and may be called upon to assist the team in a campus emergency. An up to date home telephone list is to be maintained and distributed to key MRL personnel. All MRL personnel are expected to be familiar with their role as stated in this document.

INFORMATION SOURCES IN AN EMERGENCY

In many emergencies, the campus will send a message to every voice mailbox on campus with a report about the status of the campus and any expectations about whether employees are expected to come to work. The procedure to check one's voice mailbox from off campus is to call 893-8800, enter the last 4 digits of one's campus phone number when prompted for the mailbox number, press the * key, and then enter the 4 digit password when prompted. The following radio stations should have information about emergency conditions: KCSB 91.9 FM, KTMS 1250 AM, KUHL 1440 AM Santa Maria, and KVEN 1450 AM Ventura. KEYT Channel 3 and KCOY Channel 12 may have information on TV. The campus has set up an out of area telephone line for emergency information that is expected to survive a regional disaster. Calls are 55¢. The number is (900) 200-8272. Conditions of state highways are provided by Cal Trans at (800) 427-7623. If the Emergency Operations Center is operational, they may have a recorded message about campus status at 893-8690. See also **Campus Emergency Information**

EMERGENCY DURING WORKING HOURS

Emergency Affecting the Entire Campus

If there is an emergency that affects the entire campus, but the MRL seems relatively safe, such as an earthquake, brush fire, or flood, the first duty would be to determine the actual status of the MRL building. Is anyone injured? Were any chemicals released? Is there any obvious damage to the building? Are communications functional? If there is no compelling reason to leave, personnel should stay at work keeping out of other hazardous areas, staying out of gridlocked traffic, and staying out of the way of emergency workers. The HCC or Alternate should determine if the Emergency Operations Center (EOC) has been activated. If it has, the HCC should see to it that a Departmental Emergency Status Report is filled out and delivered to the EOC. It should be faxed to x8659, if possible. If fax is not possible, it should be carried to the EH&S Building, Bldg. 565, room 1045. This building is on the north side of campus between the Facilities Yard and the Rec-Cen on Mesa Road. The HCC should then check for any additional information and let the rest of the department know about the status of the campus and community. As a member of the ERT, the HCC may be called to work with the ERT during a campus emergency; if this happens, the Alternate HCC will assume all HCC duties at the MRL Building.

Evacuation of MRL Building

If it becomes necessary to evacuate the building or if any building alarm calls for evacuation, then every person should do so as quickly as possible. Even if the alarm is known to be a test or an exercise, all persons are required to exit the building. No one is assigned the duty of forcing anyone else to leave. If possible, people should bring their valuables and lock their doors behind them as they leave the building. All people leaving the building from the upper floors should use the stairs and not use the elevator. At this time, there are no disabled persons working in the MRL Building that would require assistance leaving the building. Should a disabled person begin working at the MRL, someone will be assigned to assist them in an emergency evacuation. After leaving the building, all people should assemble at the Emergency Assembly Point (EAP) which is on the sidewalk at the southwest corner of Engineering II, **see area map for location**. Should it be unsafe to assemble there, then people should assemble at the courtyard in front of (north of) the Geology Building. If possible, the Emergency Response Kit should be brought to the EAP by Jennifer Ybarra or, if she cannot, by Melissa Ruiz. No one is to re-enter the building until authorized to do so by County Fire or by UCSB Emergency Personnel. After a big earthquake or other severe incident, the building may be closed for several days or longer. At the EAP, each person working in each area of the building should gather with the other people from that area to determine if there is anyone missing. Building areas would include the third floor, the second floor, the team room, the TEMPO lab, the Polymers lab, the Spectroscopy lab, and the X-Ray lab. A personnel status report should be passed on to the HCC or the MSO as soon as possible. If the Fire Department or other Emergency Responders are called to the MRL Building, the HCC or MSO will meet them at the MRL Building Fire Alarm Panel Box as soon as possible after an alarm and will then inform them about the status of the building and especially its personnel. The Fire Alarm Panel Box is located on the first floor, just outside the building on the south side, near the door to room 1278. In a campus wide incident, the HCC will see to it that a Departmental Emergency Status Report is filled out and delivered to the EOC as described above in **Emergency Affecting the Entire Campus**.

EMERGENCY AFTER HOURS
In the event of an emergency when people are not at work, people should come to work at the usual time, provided it is reasonably safe to do so and provided that roads are passable. Each individual needs to take personal responsibility for their decision about whether it is possible to come to work or not. News about campus status, road conditions, etc. may be found through sources listed above under "INFORMATION SOURCES IN AN EMERGENCY". HCC and laboratory Development Engineers should attempt to come to the MRL to determine the status of the building and its laboratories.

EMERGENCY MANAGEMENT
Additional details about how to deal with the problems that follow are provided in the UCSB Laboratory Safety Program-Chemical Hygiene Plan black 3-ring binder in the section under Emergency Management. This binder should be available in every MRL laboratory and is accessible on-line at: **http://ehs.ucsb.edu**

During an Earthquake
Do not rush outdoors. Most injuries occur from falling glass, plaster, bricks, debris, and electrical lines as people are leaving the building. Stay put during the initial shaking. Protect yourself. If possible sit or stand against a wall or doorway, or get under a fixed object (desk, table, etc.) Otherwise, cover your head and protect your body until the shaking stops. Stay away from all glass surfaces and windowed hallways (windows, mirrors, etc.) and cabinets and bookshelves. ABOVE ALL, REMAIN CALM. Think before you act and resist the urge to panic.

After an Earthquake
Remember aftershocks may occur at any moment with nearly the same force as the

original quake -- so be prepared. After the initial shock, and only after the shaking stops, survey your area for damage and trapped persons. If severe building damage has occurred or if life-threatening conditions are observed, evacuate the building as described above and go to the EAP, on the sidewalk at the southwest corner of Engineering II. Do not use the elevators for evacuation. Once outside the building, move into the open areas. Do not stand under overhangs on the outside of a building. They are usually the most structurally unsound part of the building, and the first to collapse or fall. Move away from power lines, and stay away from all structures.

Discovery of a Fire

Upon initial discovery of a fire, alert personnel in the immediate vicinity. If possible, put the fire out by covering it or using a fire extinguisher. If there is time or it would be helpful, ask someone to get the HCC for assistance. After the fire is out, let the HCC know what happened as soon as possible. Anytime a fire extinguisher is used it must be recharged; call x3305 to have it recharged. If the fire cannot be put out, evacuate the area, close the doors to the room where the fire is located, and activate a Fire Alarm Pull Station or call 9-911 to report the fire. Once outside, let the HCC and MSO know what happened as soon as possible. Any fire in the MRL Building may contain hazardous materials along with any smoke. Stay upwind from any smoke or fire and avoid breathing any fumes. Any fire must be reported to the campus Fire Marshall. Usually the HCC will make this report.

Hazardous Chemical Release

If possible, a small and not too harmful chemical spill should be cleaned up immediately by the person who caused the spill. Appropriate personal protective equipment must be used. If there is any doubt about what to do, contact the HCC and/or the Development Engineer for that lab. Spill cleanup kits are available in Room 1023, 1033 and most other MRL wet labs. After the spill is cleaned up, let both the HCC and the lab Development Engineer know what occurred. In the event of a larger or more hazardous chemical release, evacuate the area immediately. Close off the room where the spill occurred. Contact the HCC or the lab Development Engineer immediately. For outside assistance, call the EH&S 24 hour hotline at x3194. For a very large or very hazardous spill call x3194 and contact the HCC IMMEDIATELY. Every chemical spill must be reported to EH&S within one day of the spill. Usually the HCC will make this report.

Utility Failure

Natural Gas Leak: If a strong smell of natural gas is detected, cease all operations; evacuate the area, and call the Campus Emergency Number, 9-911. DO NOT do anything that might cause a spark, such as turning a light switch or any electrical equipment on or off. Notify the HCC. Ventilation Problem: If odors come from the ventilation system, notify Facilities Management Dispatch at x2661, EH&S at x3194, and the HCC. If the odor seems as if it may be harmful, evacuate the area until it is investigated. If the odor suggests that a fire is in progress, activate the nearest Fire Alarm Pull Station or call 9-911. Other non-hazardous utility failures should be reported to FM at x2661 or to Amanda Strom.

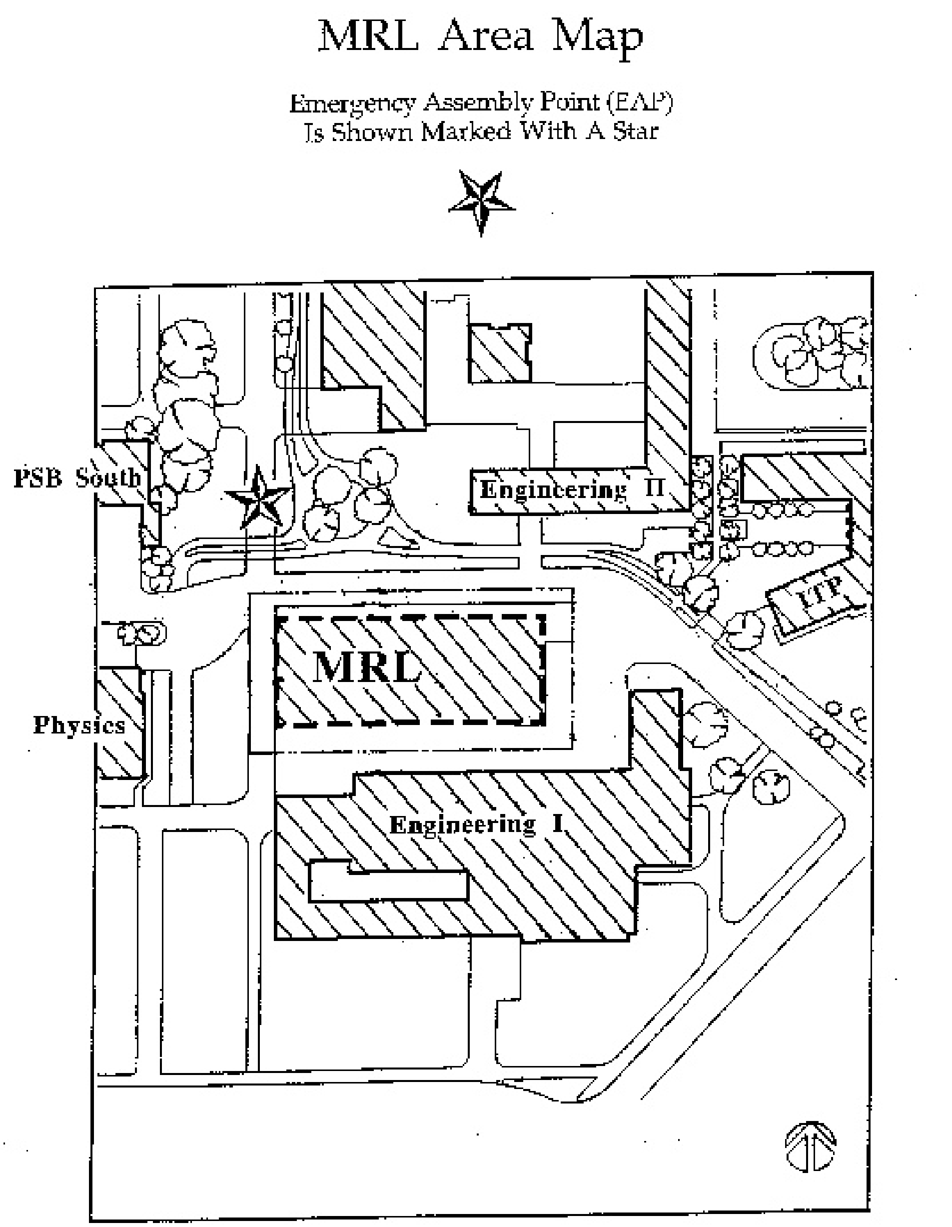
Medical Emergency

People with serious medical problems need professional help immediately. In the worst cases, call 9-911 for paramedics or an ambulance. If the sick or injured person can travel: students may be taken to Student Health Services during working hours, x3371; and anyone may be taken to the Emergency Room at Goleta Valley Cottage Hospital at 351 S. Patterson Avenue, just south of Hollister Avenue in Goleta. Employees injured on the job may be covered by Worker's Compensation. Campus Business Services guidelines about how medical service is to be provided in such cases has been inconsistent. Information about current policy for non-emergency treatment can be obtained by calling Mari Tyrrell-Simpson in Business Services at x4169. Any employee injured while working at or for UCSB is responsible to report the injury to the HCC or MSO as soon as possible. The term "employee" includes graduate students and anyone getting any kind of paycheck. California law requires that the "Employee Claim for Worker's Compensation Benefits" be given to any injured employee within one working day from the time the injury was reported to the employer.

FULL EH&S MODEL EMERGENCY OPERATION PLAN AVAILABLE

The UCSB EH&S has written a model department EOP that contains a wealth of information and is very comprehensive. In the interest of brevity and with the expectation that MRL personnel will actually read it, this MRL EOP has been made as short as possible. Copies of the Model EOP are available at the MRL Safety Bulletin Board, from the HCC and from the MSO. In addition, it can be found on-line at: **http://ehs.ucsb.edu/**

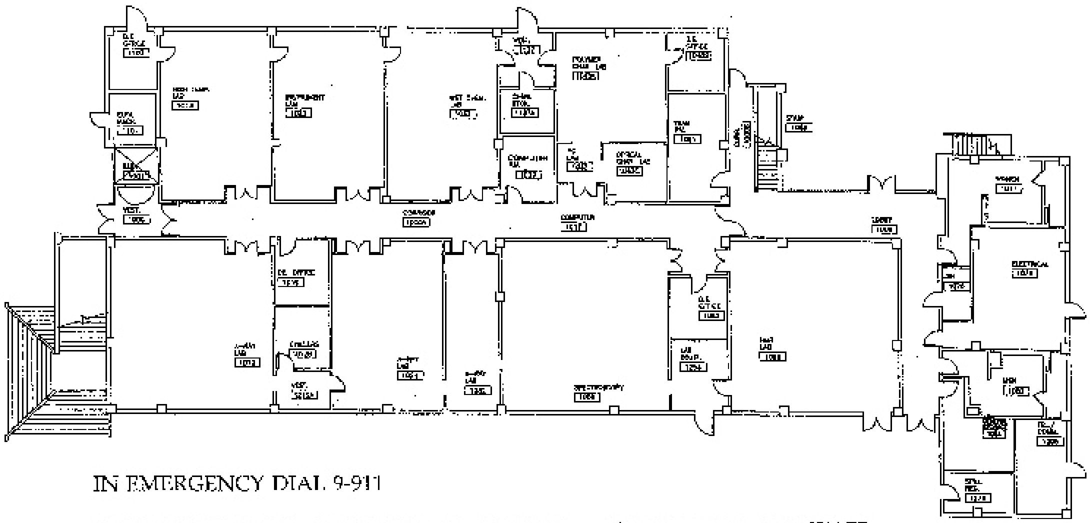
MRL Area Map


MRL Area Map
Emergency Assembly Point (EAP)
Is Shown Marked With A Star
PSB South
Engineering II
ITP
MRL
Physics
Engineering I

Emergency exit plans for floors 1 through 3

EMERGENCY EXIT PLAN

MRL FIRST FLOOR



IN EMERGENCY DIAL 9-911

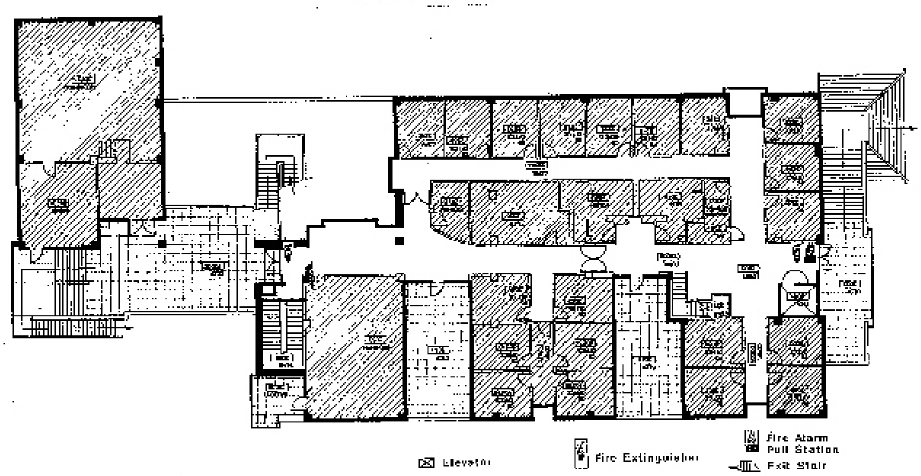
EMERGENCY SIGNALS: VOICE ANNOUNCEMENT & FLASHING LIGHT = EVACUATE

IN CASE OF FIRE USE STAIRWAY FOR EXIT

DO NOT USE ELEVATOR

EMERGENCY EXIT PLAN

MRL SECOND FLOOR



IN EMERGENCY DIAL 9-911

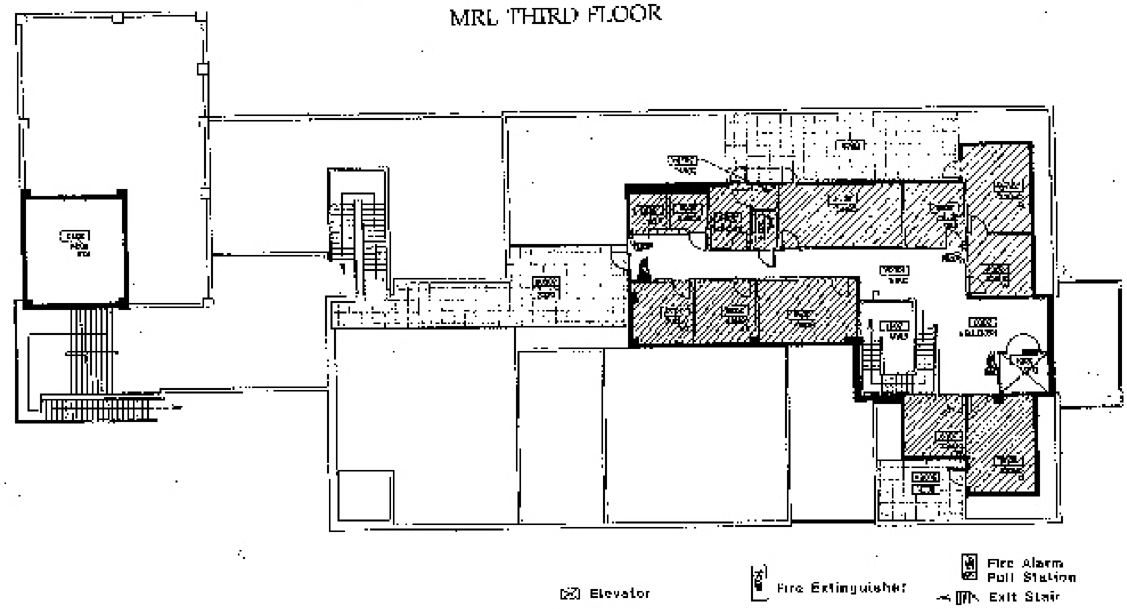
EMERGENCY SIGNALS: VOICE ANNOUNCEMENT & FLASHING LIGHT – EVACUATE

IN CASE OF FIRE USE STAIRWAY FOR EXIT

DO NOT USE ELEVATOR

EMERGENCY EXIT PLAN

MRL THIRD FLOOR



IN EMERGENCY DIAL 9-911

EMERGENCY SIGNALS: VOICE ANNOUNCEMENT & FLASHING LIGHT = EVACUATE

IN CASE OF FIRE USE STAIRWAY FOR EXIT
DO NOT USE ELEVATOR

Appendix D: MRL Combined Injury & Illness Prevention Plan and Hazard Communication Plan

This appendix reproduces the MRL Combined Injury & Illness Prevention Plan and Hazard Communication Plan, accessed on 5/6/2021 via

http://www.mrl.ucsb.edu/mrl-injury-illness-prevention-plan

**Materials Research Laboratory Combined
Injury & Illness Prevention Plan and
Hazard Communication Plan**

This document is formally adopted by the Materials Research Laboratory.

Dr. Ram Seshadri
Director

It is the policy of the Materials Research Laboratory (MRL) that all persons working under our auspices are entitled to as safe a work environment as possible. It is also our policy that all health, safety, and environmental protection regulations and good practice are to be followed by all persons working within the MRL.

This combined Injury & Illness Prevention Plan (IIPP) and Hazard Communication Plan (HCP) spell out our specific commitments to this goal.

The following policies apply to all persons working in the MRL Building and otherwise working under the auspices of the MRL, including Faculty, Staff, Post Doctoral Researchers, Graduate Students, Undergraduate Researchers, Summer Interns, and paid student helpers. All of these people will be referred to as employees.

The following people hold the offices specified in this document.

- Director: Dr. Ram Seshadri
- Hazard Communication Coordinator(HCC): Amanda Strom
- Management Services Officer (MSO) & Alternate Hazard Communication Coordinator: Sara Bard
- Chemistry Laboratory Development Engineer: Amanda Strom
- Spectroscopy Laboratory Development Engineer: Jerry Hu
- X-Ray Laboratory Development Engineer: Youli Li

Injury & Illness Prevention Plan

Title 8 of the California Code of Regulations specifies eight specific topics that must be addressed by every employer in California as part of the required IIPP. In the following the MRL adopts specific policies to meet the demands of Title 8 and to protect the people working under the MRL.

Authority & Responsibility

The Director of the MRL has the authority and responsibility to carry out the terms of this plan. The Director delegates authority for implementation of this plan to the departmental Hazard Communication Coordinator (HCC) and the departmental Management Service Officer (MSO).

Compliance with Safe Work Practices

The Director, the HCC, and the MSO are responsible to see to it that all safe work practices are followed at the MRL.

The Principal Investigators and laboratory Development Engineers are responsible to see to it that work within their laboratories follow safe work practice.

Each person working at the MRL is responsible to understand the nature and hazards of their work and to take all necessary and prudent precautions.

Communicating Safety Issues

The MRL will make sure that employees become knowledgeable about health and safety issues, practices, and protections through the following practices:

1. A Safety Bulletin Board will be maintained in Room 2042 on the second floor of the MRL Building.
2. All persons working within MRL laboratories are required to attend the EH&S Laboratory Safety Class at least once while at UCSB.
3. Employees are required to read the Material Safety Data Sheets (MSDS) and/or other references for all potential hazardous materials that they may come in contact with. The HCC will maintain reference materials including **Sax's Dangerous Properties of Industrial Materials**, the **Merck Index**, and hard copies of some MSDS. Computers for the downloading of MSDS are available to everyone. MSDS may be found on the Internet at **http://ehs.ucsb.edu/units/labsfty/labrsc/chemistry/lschemmsds.htm**
4. Research group meetings should address safety issues whenever helpful.
5. New employees shall be introduced to the MRL laboratories by more senior employees.
6. New or continuing employees are not to begin new procedures until they have been checked out on the apparatus or process by a more experienced team member and/or they have comprehensively studied the required operation and its hazards.

Identifying Work Place Hazards

Whenever a unsafe situation is discovered it should be reported to the Laboratory Development Engineer, the Principal Investigator, and/or the HCC.

Campus EH&S is to periodically inspect each MRL Laboratory and work place for hazards. The results of these inspections will be transmitted in written form to the MRL MSO, HCC, and Principal Investigators by EH&S.

Laboratory Development Engineers are to review laboratory safety practice and hardware periodically.

Hazard Report Forms are to be available on the Safety Bulletin Board in Room 2042 of the MRL Building. These forms may be used anonymously.

Procedures for Investigating Injuries and Illness

Any injury to an employee requires the following response:

1. Any employee injured on the job must report the injury to their supervisor, the MSO, or the HCC as soon as possible after the injury.
2. The HCC is to investigate the nature and cause of the injury.
3. EH&S may also investigate the nature and cause of the injury.
4. The "Employee Claim for Worker's Compensation Benefits Form" must be given or mailed to the injured employee within one working day from the time when the injury is reported to the employer. The employee has the option of filling out and returning this form to the MSO.
5. The injured employee's supervisor, usually the Principal Investigator or the MSO, is required to complete the "Report of Injury to Employee Form" within 24 hours of the injury and give it to the MSO.
6. The MSO will forward all injury report forms to the Campus Business Services Office and EH&S as specified in the Worker's Compensation Claim Report Procedure.

All forms may be obtained from the Campus Business Service Office at x4440, from the HCC, or from the MSO.

Procedures for Correcting Unsafe or Unhealthy Conditions

Whenever an unsafe condition is discovered the Laboratory Development Engineer, the Principal Investigator, and/or the HCC should take timely steps to mitigate or eliminate the hazard.

If the unsafe condition poses an immediate hazard to life or health the affected area must be evacuated.

If the unsafe condition does not pose an immediate threat, it should be mitigated through improved training, improved procedures, engineering controls, alternative materials, administrative controls, and/or personal protective devices.

Safety & Health Training

Each supervisor is responsible to see to it that all employees under their direction have received appropriate training for the assigned tasks. Each supervisor must also document that such training has occurred.

It is most important that each employee hear their supervisor say that they truly expect the employee to work in a safe and environmentally responsible way even if that requires that work will take more time and/or cost more money.

Record Keeping & Documentation

The MRL HCC and MSO will see to it that records are kept of safety training, laboratory inspection, and actions taken in response to laboratory inspections.

Hazard Communication Program

Most of the requirements for the HCP are covered in the IIPP above. Additional policies of the MRL follow.

Individual supervisors have the primary responsibility for implementing and assuring compliance with the HCP within their work areas. Usually the supervisor will be the Principal Investigator.

The primary focus of the program is to identify all hazardous substances used in the workplace and to identify those employees who may be exposed to hazardous substances so that appropriate training and mitigation occurs and accidents are avoided.

Each supervisor is responsible to identify those work areas and procedures which involve the potential use of or exposure to hazardous substances; and ensure that all employees in those areas are fully aware of the specific hazards and mitigation measures.

All hazardous substances used in each work area are to be identified and inventoried. A paper copy of the full inventory will be posted on or near the Safety Bulletin Board. Digital copies will be available from the HCC to MRL personnel or other responsible parties on request.

Material Safety Data Sheets for all chemicals used in the workplace are to be available for any employee to review at the Hazard Communication Coordinator's office. Such review may be over the Internet. The MRL acknowledges that MSDSs are required by law and **are often technically deficient**, therefore, other chemical safety reference data shall be kept at the HCC's office.

All employees using or potentially exposed to hazardous substances shall be trained in working safely with those hazards. New employees must be trained prior to their beginning work with the materials. Existing employees must be trained regarding the introduction of new hazardous materials into the workplace prior to using new hazardous materials. Such training may consist of verbal instructions, safety classes, reading assignments, group discussions, or other activity as assigned by the supervisor. The training shall include the following:

1. That the Department's written Hazard Communication Program, Injury and Illness Prevention Program, and Emergency Action Plan are posted near the Safety Bulletin Board and that they may be obtained from the HCC.
2. Physical and health effects of the hazardous substances to which employees may be exposed.
3. Methods and techniques (e.g., instrumentation) used to determine the presence of hazardous substances.
4. Protective measures to be implemented (e.g., work practices, personal protective equipment).
5. Emergency and first aid procedures.
6. How to read and evaluate an MSDS or labels to properly understand appropriate hazard information. How to find and use other chemical safety references.
7. Requirements of the Hazard Communication Regulation (California Code of Regulations Title 8, General Industry Safety Order 5194). Employees shall learn about this when attending EH&S's Laboratory Safety Training.

There shall be no unlabeled containers of chemical substances allowed in the workplace.

All containers must be labeled minimally with the following:

1. Name of the contents in written English, chemical symbols are not enough
2. Appropriate hazard warnings
3. The name of the person who purchased or uses the chemical
4. The expiration and target disposal date, if appropriate.

Likewise any tubing or piping carrying hazardous materials must be labeled with at least the name of the material.

Outside contractors working at the MRL must be informed about any potential chemical or physical hazards to which their workers may be exposed.

This page intentionally left blank

Appendix E: Laboratory Self-Inspection Checklist

This appendix contains a EH&S Laboratory Self-Inspection Checklist, accessed on 3/29/2023 via

https://www.ehs.ucsb.edu/sites/default/files/docs/ls/Lab_Self_InspectionChecklist_web_July2022.pdf

This page intentionally left blank

Laboratory Self-Inspection Checklist

revised July 2022

EH&S inspects all labs on campus at least annually. However, **lab supervisors should initiate regular self-inspections** (recommend minimum of twice-a-year) for the following reasons:

☐ Under California law (OSHA), supervisors (PIs) are required to: *"… include procedures for identifying and evaluating work place hazards including scheduled periodic inspections to identify unsafe conditions and work practices."*

☐ Beyond any regulatory requirements, doing regular self-inspections will clearly increase the level of safety in your area.

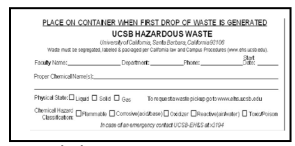
To aid you in your surveys, a Self-Inspection Checklist follows, this is not a list of every possible safety issue, but are guidelines. Most items are based on applicable regulations or campus policy. Radiation and biohazard issues are not addressed here because they are highly specialized and these labs receive targeted EH&S visits. More information is also available at http://ehs.ucsb.edu. The links (underlined) noted below lead to further information.

Hazardous Waste

1. Are personnel generating chemical waste trained with waste disposal procedures? Individuals who have not taken the UCSB Fundamentals of Lab Safety course (live or on the EH&S website) must take this course before generating hazardous waste for disposal **Online Hazardous Waste Generator training*** (EH23)
   (*This course meets the waste management training requirements enforced by Cal-EPA)

2. Is the illegal disposal of hazardous substances down the drain prevented?

3. Are all hazardous waste containers labeled with the official UCSB Hazardous Waste label?



   ☐ Is there a supply of UCSB waste labels handy (available in all campus storerooms)?
   ☐ Are labels attached when the **first drop** of waste goes into the container?
   ☐ Are all constituents in mixtures identified, as well as their concentrations?
   Do not use generic names like "*Waste or Organic waste*" instead use proper chemical name(s).
   ☐ Are chemically incompatible wastes segregated?
   ☐ Is there a designated area for storage of hazardous waste and https://www.ehs.ucsb.edu/sites/default/files/docs/hw/hazsign07.pdf?

4. Are lab personnel instructed not to dispose of chemicals by fume hood evaporation?
   By law, waste containers must be capped when not in use.

5. Is chemical waste disposed of within **9 months** of their accumulation, *regardless how much material remains inside the container*? Contact EH&S for waste disposal.

6. Are all **"sharps"** (*syringes, razor blades, etc.*) disposed in puncture resistant, leak-resistant containers and sealed tightly to preclude loss of contents? Submit an online request for EH&S disposal following the guidelines.

   Laboratory Glass: Is there a designated glass disposal container in the lab?
   Lab personnel are responsible to empty these into their bldg. red-lidded trash can – custodial staff will not do so.

7. **Obtain Free Waste Venting *Caps***: If you use Aqua Regia solutions, Piranha Solutions, Nitric acid waste, contact us (link sends e-mail) to receive free venting caps. For more info, view Vented cap video (link is external).

Chemical Safety

1. *Chemical Hygiene Plan* (CHP)

☐ Is your lab's legally-required (Cal-OSHA) CHP Lab-specific complete and shared with all workers?
☐ Has the CHP been reviewed and evaluated for effectiveness, must be done annually?
☐ Have lab personnel signed the training page?
☐ Does your CHP address your use of OSHA *Particularly Hazardous Substances* (human carcinogens, acute toxins, reproductive toxins, and pyrophorics)? Personnel working with these materials shall receive documented training.

2. Are Cal-OSHA regulated carcinogens such as formaldehyde/formalin, dichloromethane, and benzene always used in a fume hood and with appropriate gloves/eyewear?

3. Are chemical containers properly labeled with chemical name and hazard type of the material (e.g., repackaged materials and lab-synthesized materials)? No symbols or abbreviations may be used.

4. Are stored chemicals segregated according to hazard classification/compatibility (acids, bases, flammables, oxidizers, water reactives, etc.)? Compatibility Chemical Storage Chart

5. Are all containers of peroxide-forming chemicals (e.g., ethers) dated upon receipt and disposed of within the prescribed time period (contact EH&S for prompt disposal)? Peroxides can be explosively unstable.

6. Check chemical stocks regularly for materials that can become dangerously unstable over time and dispose of via EH&S. Links to descriptions of these materials can be found at: https://www.ehs.ucsb.edu/sites/default/files/docs/ls/factsheets/TimesenstiveChemicals_FS25.pdf

7. Are flammable liquids kept inside approved flammable storage cabinets whenever possible?

☐ Are flammable liquids always stored in approved flammable cabinets when in excess of 10 gallons?
☐ Do you have large volumes of flammable solvents (e.g., multiple cases or drums) in storage that are above what is reasonably needed? The quantities of flammables that can legally be stored are regulated by CA Fire Code. Please don't stockpile large quantities of these materials.
☐ Are flammable liquids stored away from sources of heat, ignition, electrical equipment or sources of static electricity?
☐ **Static Electricity** – Electrically-ground all metal containers/equipment involved in the pumping/pouring of flammable liquids to prevent buildup of static electricity as an ignition source. Flammable liquids dispensed from metal cans must be bonded and grounded to prevent a fire as explained in the laboratory SOP.

8. Are acid volumes greater than 10 gallons stored in an approved storage cabinet?

9. It is highly recommended chemical spill cleanup materials be available.
   Are all lab workers familiar with the location of spill cleanup kits?
   Spill kits are available at EHS. Contact hgacu@ucsb.edu

Note: Some lab buildings have a designated "spill closet" – generally keyed to graduate master key.

Laboratory Equipment

1. Are the eyewash and emergency shower stations free of any obstructions which would prevent ready access? These units are tested and documented by FM regularly. It is recommended that labs run their eyewash units monthly to maintain clean water in the lines.

2. Have fume hoods been EH&S tested within the year (check label)?

☐ Is an **air flow/digital indicator** present and operational? *If not, contact EHS for repair.*
☐ Is lab **equipment or chemicals** within the hood minimized? **Keep only items in use.**
☐ Are air entry slots at back of hood kept clear of obstructions? ***Cluttered hoods interfere with proper air flow.***
☐ Is the front **sash lowered** to the appropriate level when hood is in use? If the low flow alarm engages, lower the sash until the alarm stops. If the alarm continues when the sash is lowered please contact EH&S at x8243. **DO NOT** over-ride the safety alarm by permanently engaging the "Mute" or "Emergency" button (e.g., with tape, paper clips, etc.).
☐ Has everyone using a fume hood been properly trained to use their fume hood? *General fume hood use is covered in the Fundamentals of Lab Safety training course.*

3. Are biological safety cabinets certified annually or when moved (check sticker) and are they the proper types for the work being conducted?

4. Do labs using non-ionizing radiation equipment, such as lasers, microwaves, and ultraviolet light sources, have properly posted warning signs and shielded work areas? Documented training?

5. Compressed gas cylinders

☐ Are cylinders dated upon arrival and contents clearly identified?
☐ Inspect regularly for defects, i.e., excessive rust, dents, bulging, corrosion, etc.
☐ Unidentified cylinders should be marked, "CONTENTS UNKNOWN" and returned to the manufacturer.
☐ Non-lecture bottles $\geq$ 5 years old must be returned to the manufacturer to ensure they are safety/pressure tested as required by law ("hydrostatic testing") Check stamped date on cylinder when it was last tested.
☐ Corrosive gases (e.g. **HF, HBr, HCl, H_2S**) can degrade the cylinder over time and/or produce dangerously high pressures of hydrogen. Dispose of within 2 years.
☐ Are cylinders secured upright with two welded chains and brackets bolted to a wall, bench or other secure object (no C-clamps type)?
☐ Are protective caps in place while cylinders are not in use?
☐ Flammable gases (e.g. hydrogen, methane) tubing should be equipped with a **flash arrestor** to prevent flame flashback to cylinder. Available from gas vendors.
☐ Ensure gas tubing is appropriate for the material being used.
☐ Do not use Teflon tape or "pipe dope" on CGA connections unless specified by the equipment manufacturer. Particularly avoid this with oxygen systems.
☐ Use of large cylinders of highly toxic gases must be reviewed/approved (contact EH&S, x-4899)
☐ Highly toxic gas cylinders should be equipped with a **reduced flow orifice** (RFO) connection to prevent rapid discharge of cylinder contents. Available from gas vendors.
☐ Gas cabinets with toxic or flammable gas delivery manifolds often have an **excessive flow detection and auto-shutoff valve** built-in. Verify that this safety feature is functional.

6. Lab refrigerators

☐ Are refrigerators for storing flammables clearly posted with signage indicating they are safe for such storage? (e.g. "desparked", "lab-safe", "explosion-proof", "flammable storage").
☐ Are refrigerators that are **NOT** designed for flammables storage clearly marked as such? (this is very important to prevent a potential explosion)
☐ Are all chemical storage refrigerators marked with "*No Food*" labels?
☐ Refrigerators in labs utilized for food or drinks should be marked "*Food Only/No Chemicals*?"

7. Is the location of manuals/instructions for each piece of equipment known?

8. Are the belt guards in place on all pumps, etc.?

9. **Solvent stills with water-reactive drying agents**

- Are solvent stills clearly labeled with the solvent name and drying reagent?

- Ensure water-flow monitor are installed that would automatically shut off the heating mantles in the event of cooling water loss (pic with arrow). Periodically test monitors by shutting down the water flow to verify the system is functioning properly. They are available commercially.
  We strongly recommend this important safety device be adopted. Fires associated with stills are not uncommon, including the $3M fire at UCI in 2001.

- Ensure secondary containment pans are beneath the stills. In the event of a system leak this should capture any leakage and prevent the solvent from spreading out and finding an ignition source.

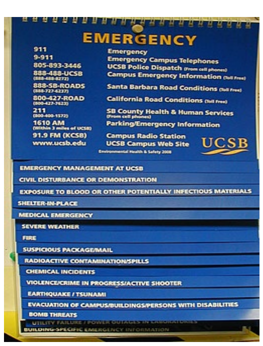
- **Quenching Solvent Stills -**The quenching of used still-pots is potentially dangerous but can be done safely if appropriate precautions are taken. "See EH&S Fact Sheet on still quenching"

· ***Pressurized Systems*** - Inspect and test all high-pressure vessels regularly per the owner's manual requirements. Each vessel should have a use-log of: *experiment conditions, dates of runs, testing/maintenance history, etc*. in order to track the vessel's life-expectancy. Pressure vessels must include a functional over-pressurization rupture disk to prevent a catastrophic vessel failure.

General Safety Concerns

1. Has EH&S posted outside the lab an emergency information contact sign, indicating the hazards within, responsible persons and phone numbers? Is the information correct? Call EH&S to update (x-8243).

2. Has the UCSB Campus Emergency Flip Chart been posted in the work area? Has the, *Building-Specific Emergency Information section* page been completed?



3. Are rooms containing regulated hazardous substances, such as infectious and radioactive materials, posted with warning/caution signs and appropriate authorizations?

4. Are aisles free of obstructions? Minimum clearance for lab aisles is 2 ft.

5. Do work areas have adequate ventilation and illumination? To prevent suffocation, verify that fresh air is supplied to cold/hot rooms that are used as work areas. Check emergency door release and alarm mechanisms.

6. Are fire extinguishers functional (plastic seal and metal pin intact and dry powder units show pressure)? Are the extinguishers located on their wall hooks? Is the area in front of the extinguishers accessible?

7. Are food and beverages kept out of chemical work areas and out of laboratory refrigerators?

8. Is everyone familiar with the UCSB Laboratory Personal Protective Equipment (PPE) Policy? Minimum attire: Full length pants (or equivalent) and closed toe/heel shoe attire must be worn at all times by all workers who are occupying or entering a *laboratory/technical* area; unless exceptions have been determined per policy.

   For more PPE information, including glove reference charts, click link.

   a. Any extra or unwanted lab coats in the laboratory? To recycle unwanted coats, drop them into a designated bin located in the same locations as the existing coat laundering stations. *It is important to only issue new workers coats via the LHAT and campus PPE storeroom, so that the coat issuance can be legally documented and the individual gets the proper type and size of coat.*

9. Have all respirator and dusk mask users been certified by the EH&S Respiratory Protection Program?


10. Is the level of housekeeping in the lab satisfactory**?**

WHAT TO LOOK FOR IN YOUR LAB:
No hazardous materials stored on floor and away from the edge of lab bench
Aisles, secondary exits and corridors kept clear
Keep lab benches and hoods as uncluttered as possible.
Glassware that is scattered on benches and out in the open clutters working areas, is easily broken, will not stay clean, and, if dirty, may be confused for clean glassware and could potentially negate any viable research.

11. Lab doors are fire-rated and therefore cannot be propped open with a wedge or other device. Discontinue use of these, or SB County Fire may confiscate them and cite the University.

12. Secure your highly hazardous materials, e.g. highly toxic gas, radiation, select biological agents. Ensure the lab door(s), freezers, refrigerators, storage cabinets, etc. with these materials are locked whenever the lab is unattended.

Electrical Safety

1. Check electrical equipment and inspect for frayed cords and damaged connections? Electrical tape is prohibited.

2. Multiple outlet strips plugged directly into a wall outlet? Does the power strip have a circuit breaker? Extension cords are not to be permanently used with power strips.

3. Are employees instructed **not** to use extension cords in place of permanent wiring (use allowed if only on a temporary, immediate, basis)? Have permanent receptacles installed for long-term electricity needs.

- Ensure extension cords are 14-gauge (heavy duty) at a minimum, and **temporarily** servicing only one appliance or fixture?
- Ensure extension cord is plugged directly into receptacle. Extension cords should never be used plugged end-to-end; use the proper length cord.
- If extension cords are used, ensure cords are not running through walls, ceiling or doors?

4. Are cord guards provided across an aisle or other passageway to prevent tripping?

5. Is the electrical equipment grounded (three-prong plugs) or double insulated?
   – Are 3-prong plugs only used for 3-prong receptacles, and never altered to fit into an outlet?

6. Are Ground Fault Circuit Interrupters in place where electrical outlets are in use within 6 feet of water? Ensure GFCI's are working properly by using the "TEST" button.

7. Are all electrical boxes, panels and receptacles covered to protect against electrocution?

8. Are control switches, circuit breakers and electrical panels free of obstructions? These items must be accessible at all times.

9. Are high voltage control panels and access doors posted?

Seismic Safety

1. Do shelves used for chemical storage have seismic restraining devices (e.g. lip, wire or bungee cord) installed to prevent chemicals from falling? Is all valuable or hazardous equipment seismically anchored?

   External links for securing lab instruments & equipment:

   Earthquake Restraint System for Optical Tables

   Securing Your Workplace

2. Are cabinets, chemical shelves and furniture over 42 inches in height braced against walls to prevent their falling over in the event of an earthquake?

3. Is overhead storage of heavy objects minimized and restrained?

Administrative

(Note: these training requirements must be met by supervisors to satisfy their personal regulatory obligations and reduce their liability)

1. Per UCOP policy the Fundamentals of Laboratory Safety orientation is required for all new UCSB lab workers before lab access is granted. Verify everyone has attended either the Initial course or the refresher (this is required annually after completing the *Initial* training) training.

2. Ensure everyone has gone through the Laboratory Hazard Assessment Tool (LHAT)?
   The LHAT provides a summary report of hazards present in the laboratory and the PPE recommended for laboratory workers. The LHAT must be updated as hazards change, and at least once every 12 months, irrespective of changes to hazards or personnel.

3. Has each lab member completed the Training Needs Assessment form and kept on file for review? Supervisors are responsible for conducting and documenting the laboratory training needs assessment per policy.

Any questions, please contact hgacu@ucsb.edu

This page intentionally left blank

Appendix F: Lab Hazard Assessments for the Safinya Labs

This appendix contains relevant parts of the certified laboratory hazard assessments for the three Safinya labs, accessed on 5/6/2021 via

https://ehs.ucop.edu/

These assessments are current as of the date of the last revision of this CHP. As a lab member, you can use the above link at any time to view the current and full assessments after you log in. Therefore, these assessments are not provided in the hardcopy version of the CHP.

Note:

The assessment for the LOM area (room 1012A) shows no lab hazards.

This page intentionally left blank

Main MRL labs Assessment - Certified [Oct 30, 2020 - Oct 30, 2023]

This assessment evaluates the activities in a lab or research environment to identify potential hazards. These activities can pose chemical, physical, biological, radiological, laser and non-ionizing radiation hazards.

Group:

Main MRL labs

Owner: Cyrus Safinya

Rooms: Materials Research Lab - 1012, 1012B, 1024, 1032

Document Name:

Main MRL labs Assessment

Main MRL labs Assessment - Certified [Oct 30, 2020 - Oct 30, 2023]

Chemical Hazards

C2. Working with hazardous liquids or other materials which create a splash hazard ⓘ

(●) Yes ( ) No

C3. Working with small volumes (<= 4L) of corrosive liquids or solids ⓘ

(●) Yes ( ) No

C4. Working with large volumes (> 4L) of corrosive liquids or solids ⓘ

( ) Yes (●) No

C5. Working with small volumes (<= 1L) of flammable solvents/materials when no reasonable ignition sources are present ⓘ

(●) Yes ( ) No

C6. Working with large volumes (> 1L) of flammable solvents/materials ⓘ

(●) Yes ( ) No

C7. Working with any quantity of flammable solvents/materials when there are reasonable ignition sources present; or working in areas where flammable concentrations of vapors or gas may be present ⓘ

( ) Yes (●) No

C8. Working with Category 1 or 2 acutely toxic chemicals ⓘ

( ) Yes (●) No

C9. Working with known or suspect human carcinogens ⓘ

(●) Yes ( ) No

C10. Working with reproductive hazard chemicals (including reproductive toxicants and germ cell mutagens) ⓘ

(●) Yes ( ) No

C11A. Working with pyrophoric chemicals (or reagents) ⓘ

(●) Yes ( ) No

C11B. Working with substances which in contact with water emit flammable gases

- (selected) Yes
- No

C12. Working with potentially explosive chemicals

- Yes
- (selected) No

C13. Working with Category 2 or higher engineered nanomaterials

- Yes
- (selected) No

C14. Minor chemical spill cleanup

- (selected) Yes
- No

C15. Major chemical spill cleanup

- Yes
- (selected) No

Main MRL labs Assessment - Certified [Oct 30, 2020 - Oct 30, 2023]

Physical Hazards

P1. Working with cryogenic liquids

(•) Yes ( ) No

P2. Working with very cold equipment, samples, or dry ice

(•) Yes ( ) No

P3. Removing sealed vials from liquid nitrogen

(•) Yes ( ) No

P4. Working with scalding liquids or hot equipment (e.g., autoclave, water bath, oil bath)

(•) Yes ( ) No

P5. Glassware washing

(•) Yes ( ) No

P6. Working with loud equipment, noises, sounds, alarms, etc.

( ) Yes (•) No

P7. Working with a high-powered sonicator

( ) Yes (•) No

P8. Working with a centrifuge

(•) Yes ( ) No

P9. Working with sharps (e.g. needles, razor blades and broken glass)

(•) Yes ( ) No

P10. Working with an apparatus containing materials under pressure or vacuum

(•) Yes ( ) No

P11. Working with a microtome

( ) Yes (•) No

Main MRL labs Assessment - Certified [Oct 30, 2020 - Oct 30, 2023]

Biological Hazards

B1. Working with human or non-human primate blood, body fluids, tissues, cells or other potentially infectious material (OPIM) which may contain human bloodborne pathogens (BBP)

ⓘ

○ Yes ◉ No

B2. Working with microbial agents (bacteria, virus, parasites, yeast, fungi, prions), recombinant DNA and/ or biological materials (cells, tissues, fluids) exposed to or likely to contain Risk Group 1 microbial agents or recombinant DNA (BSL-1)

ⓘ

○ Yes ◉ No

B3. Working with microbial agents, recombinant DNA and/or biological materials (cells, tissues, fluids) exposed to or likely to contain Risk Group 2 microbial agents or recombinant DNA (BSL-2)

ⓘ

○ Yes ◉ No

B4. Working with microbial agents, recombinant DNA and/or biological materials (cells, tissues, fluids) exposed to or likely to contain Risk Group 2 microbial agents or recombinant DNA for which Biosafety Level 3 practices are required (BSL-2+)

ⓘ

○ Yes ◉ No

B5. Working with microbial agents, recombinant DNA and/or biological materials (cells, tissues, fluids) exposed to or likely to contain Risk Group 3 microbial agents or recombinant DNA (BSL-3)

ⓘ

○ Yes ◉ No

B6. Working with live animals only or in conjunction with Risk Group 1 microbial agents or recombinant DNA (ABSL-1)

ⓘ

○ Yes ◉ No

B7. Working with infected or potentially infectious live animals alone or in conjunction with Risk Group 2 microbial agents or recombinant DNA (ABSL-2)

ⓘ

○ Yes ◉ No

Main MRL labs Assessment - Certified [Oct 30, 2020 - Oct 30, 2023]

Laser Hazards

L1. Open Beam - Performing alignment, trouble-shooting or maintenance that requires working with an open beam and/or defeating the interlocks on any Class 3 or Class 4 laser system

- ○ Yes
- ◉ No

L2. Open Beam - Viewing a Class 3R laser beam with magnifying optics

- ○ Yes
- ◉ No

L3. Open Beam - Working with a Class 3B laser open beam system with the potential for producing direct or specular reflections

- ○ Yes
- ◉ No

L4. Open Beam - Working with a Class 4 laser open beam system with the potential for producing direct, specular or diffuse reflections

- ○ Yes
- ◉ No

L5. Non-Beam - Handling dye laser materials such as dyes, chemicals, and solvents

- ○ Yes
- ◉ No

L6. Non-Beam - Maintaining and repairing power sources for large Class 3B and Class 4 lasers

- ○ Yes
- ◉ No

L7. Enclosed Beam - Using a Class 1 device housing a Class 3B or Class 4 enclosed or embedded laser with the potential for beam exposure during a servicing event

- ◉ Yes
- ○ No

Main MRL labs Assessment - Certified [Oct 30, 2020 - Oct 30, 2023]

Radiological Hazards

R1. Working with unsealed radioactive materials including generally licensed radioactive material or devices (e.g., uranyl acetate thorium nitrate, 32P-labeled biomolecules)

(•) Yes ( ) No

R2. Working with unsealed radioactive materials in hazardous chemicals (corrosives, flammables, liquids, powders, etc.)

( ) Yes (•) No

R3. Working with sealed radioactive sources or devices containing sources of radioactive materials (e.g., liquid scintillation counters, gas chromatographs/electron capture detectors, static eliminators, etc.)

( ) Yes (•) No

Non-Ionizing Radiation Hazards

N1. Working with unshielded sources of ultraviolet radiation

- ( ) Yes
- (•) No

N2. Working with intense infrared emitting equipment (e.g. glass blowing)

- ( ) Yes
- (•) No

Certified: **09/16/2022**

Expiration: **09/16/2025**

This assessment evaluates the activities in a lab or research environment to identify potential hazards. These activities can pose chemical, physical, biological, radiological, laser and non-ionizing radiation hazards.

Group: Cell Lab

Rooms: Materials Research Lab - 1016

Principal Investigator, Supervisor or other Responsible Person Details:

Name: Cyrus Safinya

Email: safinya@mrl.ucsb.edu

Phone: 805-893-8635

Document Name

Cell Lab Assessment

Certified: **09/16/2022**

Expiration: **09/16/2025**

Chemical Hazards

C2. Working with hazardous liquids or other materials which create a splash hazard *

Yes No

C3. Working with small volumes (<= 4L) of corrosive liquids or solids *

Yes No

C4. Working with large volumes (> 4L) of corrosive liquids or solids *

Yes No

C5. Working with small volumes (<= 1L) of flammable solvents/materials when no reasonable ignition sources are present *

Yes No

C6. Working with large volumes (> 1L) of flammable solvents/materials *

Yes No

C7. Working with any quantity of flammable solvents/materials when there are reasonable ignition sources present; or working in areas where flammable concentrations of vapors or gas may be present *

Yes No

C8. Working with Category 1 or 2 acutely toxic chemicals *

Yes No

C9. Working with known or suspect human carcinogens *

Yes No

C10. Working with reproductive hazard chemicals (including reproductive toxicants and germ cell mutagens) *

Yes No

C11A. Working with pyrophoric chemicals (or reagents) *

Yes No

C11B. Working with substances which in contact with water emit flammable gases *

Yes No

C12. Working with potentially explosive chemicals *

Yes No

C13. Working with Category 2 or higher engineered nanomaterials *

Yes No

C14. Minor chemical spill cleanup *

Yes No

C15. Major chemical spill cleanup *

Yes No

Certified: **09/16/2022**

Expiration: **09/16/2025**

Physical Hazards

P1. Working with cryogenic liquids *

- ○ Yes
- ◉ No

P2. Working with very cold equipment, samples, or dry ice *

- ○ Yes
- ◉ No

P3. Removing sealed vials from liquid nitrogen *

- ◉ Yes
- ○ No

P4. Working with scalding liquids or hot equipment (e.g., autoclave, water bath, oil bath) *

- ◉ Yes
- ○ No

P5. Glassware washing *

- ○ Yes
- ◉ No

P6. Working with loud equipment, noises, sounds, alarms, etc. *

- ○ Yes
- ◉ No

P7. Working with a high-powered sonicator *

- ○ Yes
- ◉ No

P8. Working with a centrifuge *

- ◉ Yes
- ○ No

P9. Working with sharps (e.g. needles, razor blades and broken glass) *

- ◉ Yes
- ○ No

P10. Working with an apparatus containing materials under pressure or vacuum *

- ○ Yes
- ◉ No

P11. Working with a microtome *

- ○ Yes
- ◉ No

Certified: **09/16/2022**

Expiration: **09/16/2025**

Biological Hazards

B1. Working with human or non-human primate blood, body fluids, tissues, cells or other potentially infectious material (OPIM) which may contain human bloodborne pathogens (BBP) *

(●) Yes ( ) No

B2. Working with microbial agents (bacteria, virus, parasites, yeast, fungi, prions), recombinant DNA and/ or biological materials (cells, tissues, fluids) exposed to or likely to contain Risk Group 1 microbial agents or recombinant DNA (BSL-1) *

(●) Yes ( ) No

B3. Working with microbial agents, recombinant DNA and/or biological materials (cells, tissues, fluids) exposed to or likely to contain Risk Group 2 microbial agents or recombinant DNA (BSL-2) *

(●) Yes ( ) No

B4. Working with microbial agents, recombinant DNA and/or biological materials (cells, tissues, fluids) exposed to or likely to contain Risk Group 2 microbial agents or recombinant DNA for which Biosafety Level 3 practices are required (BSL-2+) *

( ) Yes (●) No

B5. Working with microbial agents, recombinant DNA and/or biological materials (cells, tissues, fluids) exposed to or likely to contain Risk Group 3 microbial agents or recombinant DNA (BSL-3) *

( ) Yes (●) No

B6. Working with live animals only or in conjunction with Risk Group 1 microbial agents or recombinant DNA (ABSL-1) *

( ) Yes (●) No

B7. Working with infected or potentially infectious live animals alone or in conjunction with Risk Group 2 microbial agents or recombinant DNA (ABSL-2) *

( ) Yes (●) No

Certified: **09/16/2022**

Expiration: **09/16/2025**

Radiological Hazards

R1. Working with unsealed radioactive materials including generally licensed radioactive material or devices (e.g., uranyl acetate thorium nitrate, 32P-labeled biomolecules) *

◯ Yes ◉ No

R2. Working with unsealed radioactive materials in hazardous chemicals (corrosives, flammables, liquids, powders, etc.) *

◯ Yes ◉ No

R3. Working with sealed radioactive sources or devices containing sources of radioactive materials (e.g., liquid scintillation counters, gas chromatographs/electron capture detectors, static eliminators, etc.) *

◯ Yes ◉ No

Certified: **09/16/2022**

Expiration: **09/16/2025**

Laser Hazards

L1. Open Beam - Performing alignment, trouble-shooting or maintenance that requires working with an open beam and/or defeating the interlocks on any Class 3 or Class 4 laser system *

○ Yes ◉ No

L2. Open Beam - Viewing a Class 3R laser beam with magnifying optics *

○ Yes ◉ No

L3. Open Beam - Working with a Class 3B laser open beam system with the potential for producing direct or specular reflections *

○ Yes ◉ No

L4. Open Beam - Working with a Class 4 laser open beam system with the potential for producing direct, specular or diffuse reflections *

○ Yes ◉ No

L5. Non-Beam - Handling dye laser materials such as dyes, chemicals, and solvents *

○ Yes ◉ No

L6. Non-Beam - Maintaining and repairing power sources for large Class 3B and Class 4 lasers *

○ Yes ◉ No

L7. Enclosed Beam - Using a Class 1 device housing a Class 3B or Class 4 enclosed or embedded laser with the potential for beam exposure during a servicing event *

○ Yes ◉ No

Certified: **09/16/2022**

Expiration: **09/16/2025**

Non-Ionizing Radiation Hazards

N1. Working with unshielded sources of ultraviolet radiation *

○ Yes ◉ No

N2. Working with intense infrared emitting equipment (e.g. glass blowing) *

○ Yes ◉ No

Appendix G: Additional Information on Safe Use of Pyrophoric and Water-Reactive Materials

The EH&S laboratory safety fact sheets in this appendix are also available online at

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/fact-sheets;

They are current as of the last revision of this CHP).

(The article "Safe handling of organolithium compounds in the laboratory" is referenced in one of the fact sheets but with an incorrect URL.)

This page intentionally left blank

LABORATORY SAFETY FACT SHEET #34

Pyrophoric Organolithium Reagents

Procedures[1] for Safe Use of Pyrophoric Organolithium Reagents

Scope

Storage, transfer and use of organolithium reagents including (but not necessarily limited to):

Alkyls –

- Methyl-d3-lithium, as complex with lithium iodide solution 0.5 M in diethyl ether
- Methyllithium lithium bromide complex solution
- Methyllithium solution purum, ~5% in diethyl ether (~1.6M)
- Methyllithium solution purum, ~1 M in cumene/THF
- Methyllithium solution 3.0 M in diethoxymethane
- Methyllithium solution 1.6 M in diethyl ether
- Ethyllithium solution 0.5 M in benzene/cyclohexane (9:1)
- Isopropyllithium solution 0.7 M in pentane
- Butyllithium solution 2.0 M in cyclohexane
- Butyllithium solution purum, ~2.7 M in heptane
- Butyllithium solution 10.0 M in hexanes
- Butyllithium solution 2.5 M in hexanes
- Butyllithium solution 1.6 M in hexanes
- Butyllithium solution 2.0 M in pentane
- Butyllithium solution ~1.6 M in hexanes
- Butyllithium solution technical, ~2.5 M in toluene
- Isobutyllithium solution technical, ~16% in heptane (~1.7 M)
- sec-Butyllithium solution 1.4 M in cyclohexane
- tert-Butyllithium solution purum, 1.6-3.2 M in heptane
- tert-Butyllithium solution 1.7 M in pentane
- (Trimethylsilyl)methyllithium solution 1.0 M in pentane
- (Trimethylsilyl)methyllithium solution technical, ~1 M in pentane
- Hexyllithium solution 2.3 M in hexane
- 2-(Ethylhexyl)lithium solution 30-35 wt. % in heptane

Alkynyls –

- Lithium acetylide, ethylenediamine complex 90%
- Lithium acetylide, ethylenediamine complex 25 wt. % slurry in toluene
- Lithium (trimethylsilyl)acetylide solution 0.5 M in tetrahydrofuran
- Lithium phenylacetylide solution 1.0 M in tetrahydrofuran

Aryls –

- Phenyllithium solution 1.8 M in di-n-butyl ether

Others –

- 2-Thienyllithium solution 1.0 M in tetrahydrofuran
- Lithium tetramethylcyclopentadienide
- Lithium pentamethylcyclopentadienide

Hazards

In general these materials are pyrophoric; they ignite spontaneously when exposed to air. This is the primary hazard and reagents must be handled so as to rigorously exclude air/moisture. They all tend to be toxic and come dissolved in a flammable solvent. Other common hazards include corrosivity, teratogenicity, water reactivity, peroxide formation, along with damage to the liver, kidneys, and central nervous system.

On 12/29/2008 a UCLA lab employee, wearing nitrile gloves, safety glasses but no a lab coat, with three months work experience in this lab was transferring an aliquot of t-butyllithium in pentane when the syringe plunger popped out or was pulled out of the syringe barrel. The employee was splashed with the pyrophoric and flammable solution; upon contact with air the mixture immediately caught fire. The fire ignited the gloves and a sweater she wore. She suffered 3rd degree burns to 40% of her body and died about three weeks later.

Controlling the Hazards

BEFORE working with pyrophoric reagents, read the relevant Material Safety Data Sheets (MSDS) and understand the hazards. The MSDS must be reviewed before using an unfamiliar chemical and periodically as a reminder. Pyrophorics users must be thoroughly-trained in proper lab technique and working alone with pyrophorics is strongly discouraged.

Set up your work in a laboratory fume hood or glove box and ALWAYS wear the appropriate personal protective equipment. Minimize the quantity of pyrophoric reagents used and stored. The use of smaller syringes is encouraged. If handling more than 20 ml of sample - one should use a cannula for transfer or use a 20 ml syringe repeatedly.

Personal Protective Equipment (PPE)

Eye Protection

- Chemical Splash goggles or safety glasses that meet the ANSI Z.87.1 1989 standard must be worn whenever handling pyrophoric chemicals. Ordinary prescription glasses will NOT provide adequate protection unless they also meet this standard. When there is the potential for splashes, goggles must be worn, and when appropriate, a face shield added.
- A face shield is required any time there is a risk of explosion, large splash hazard or a highly exothermic reaction. All manipulations of pyrophoric chemicals which pose this risk should occur in a fume hood with the sash in the lowest feasible position. Portable shields, which provide protection to all laboratory occupants, are acceptable.

Skin Protection

- Gloves must be worn when handling pyrophoric chemicals. Nitrile gloves should be adequate for handling most of these in general laboratory settings but they are combustible. Be sure to use adequate protection to prevent skin exposures. Sigma-Aldrich recommends the use of nitrile gloves underneath neoprene gloves[2].
- *A lab coat or apron* (not made from easily ignited material like nylon or polyester) *must be worn*. Special fire-resistant lab coats made from Nomex are more expensive, but recommended for labs using these reagents routinely.
- No open toe shoes are allowed.

Equipments and Notification

- Have the proper equipment and the phone number for the Police (9-911) readily available for any emergencies.

Designated Area

Eyewash

- Suitable facilities for quick drenching or flushing of the eyes should be within 10 seconds travel time for immediate emergency use. Bottle type eyewash stations are not acceptable.

Safety Shower

- A safety or drench shower should be available within 10 seconds travel time where pyrophoric chemicals are used.

Fume Hood

- Many pyrophoric chemicals release noxious or flammable gases and should be handled in a laboratory hood. In addition, some pyrophoric materials are stored under kerosene (or other flammable solvent), therefore the use of a fume hood (or glove box) is required to prevent the release of flammable vapors into the laboratory.

Glove (dry) box

- Glove boxes are an excellent device to control pyrophoric chemicals when inert or dry atmospheres are required.

Important Steps to Follow

Handling pyrophoric Reagents –

- By using proper syringe techniques, these reagents can be handled easily in the laboratory.

The Aldrich Sure/Seal™ Packaging System

The Sure/Seal packaging system (**Fig. 1A)** provides a convenient method for storing and dispensing air-sensitive reagents. The reagent can be dispensed using a syringe or double-tipped needle (16, 18 or 20 gauge) inserted through the hole in the metal cap. When inserting a needle through a septum, a layer of silicone or hydrocarbon grease on the septum will help. Upon withdrawal of the needle, the small hole that remains in the PTFE liner will not cause the reagent to deteriorate under normal circumstances. However, it is recommended that the plastic cap be replaced after each use and in particular for long-term storage.

For extended storage of unused reagents, use the solid plastic cap, or equip the bottle with an Oxford Sure/Seal valve cap, or transfer the reagent to a suitable storage vessel.

The Sure/Seal septum-inlet transfer adapter (**Fig. 1B)** can be used when repeated dispensing is necessary. The adapter protects the contents of the bottles from air and moisture.

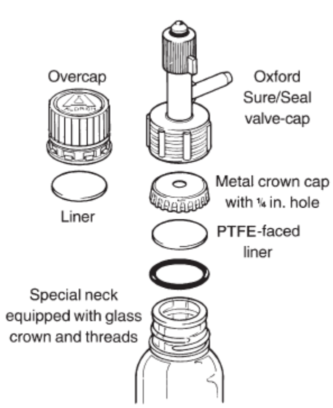


Fig. 1A Sure/Seal components

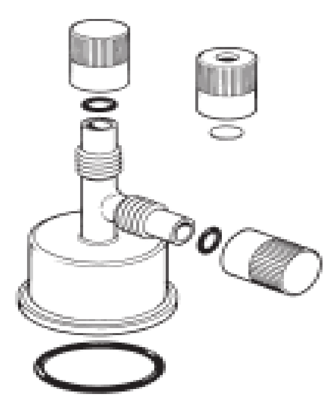


Fig. 1B Sure/Seal septum-inlet transfer adapter

Transferring Pyrophoric Reagents with Syringe

- In a fume hood or glove box, clamp the reagent bottle to prevent it from moving
- Clamp/secure the receiving vessel too.
- After flushing the syringe with inert gas, depress the plunger and insert the syringe into the Sure/Seal bottle with the tip of the needle below the level of the liquid
- Secure the syringe so if the plunger blows out of the body it, and the contents will not impact anyone (aim it toward the back of the containment)
- Insert a needle from an inert gas source carefully keeping the tip of the needle above the level of the liquid
- Gently open the inert gas flow control valve to slowly add nitrogen gas into the Sure/Seal bottle.
- This will allow the liquid to slowly fill the syringe (up to 100mL) as shown in **Fig. 2A**. Pulling the plunger causes gas bubbles.
- Let nitrogen pressure push the plunger to reduce bubbles. Excess reagent and entrained bubbles are then forced back into the reagent bottle as shown in **Fig. 2B**.
- The desired volume of reagent in the syringe is quickly transferred to the reaction apparatus by puncturing a rubber septum as illustrated in **Fig. 2C**.

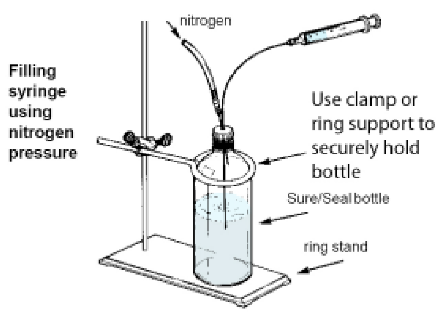


Fig.2A Filling syringe using nitrogen pressure

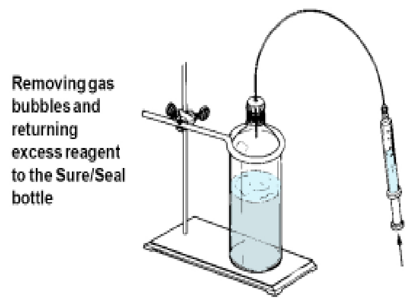


Fig. 2B Removing gas bubbles and returning excess reagentto the Sure/ Seal bottle

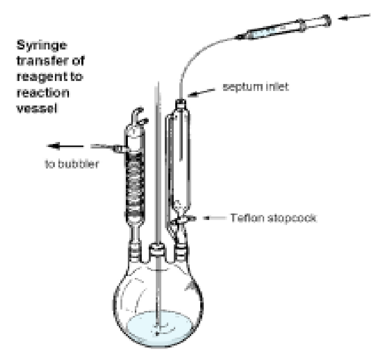


Fig. 2C Syringe transfer of reagent to reaction vessel

Transferring Pyrophoric Reagents with a Double-Tipped Needle

- The double-tipped needle technique is recommended when transferring 50 mL or more.
- Pressurize the Sure/Seal bottle with nitrogen and then insert the double-tipped needle through the septum into the headspace above the reagent. Nitrogen will pass through the needle. Insert the other end through the septum at the calibrated addition funnel on the reaction apparatus. Push the needle into the liquid in the Sure/ Seal reagent bottle and transfer the desired volume. Then withdraw the needle to above the liquid level. Allow nitrogen to flush the needle. Remove the needle first from the reaction apparatus and then from the reagent bottle. **(Fig. 3A)**
- For an exact measured transfer, convey from the Sure/Seal bottle to a dry nitrogen flushed graduated cylinder fitted with a double-inlet adapter **(Fig. 3B)**. Transfer the desired quantity and then remove the needle from the Sure/Seal bottle and insert it through the septum on the reaction apparatus. Apply nitrogen pressure as before and the measured quantity of reagent is added to the reaction flask.
- To control flow rate, fit a Luer lock syringe valve between two long needles as shown in **(Fig. 3C)**.

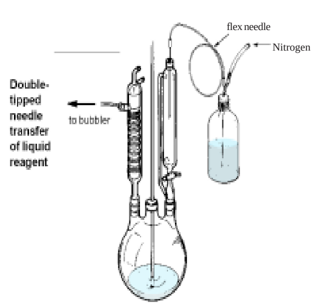


Fig. 3A Double-tipped needle transfer of liquid reagent

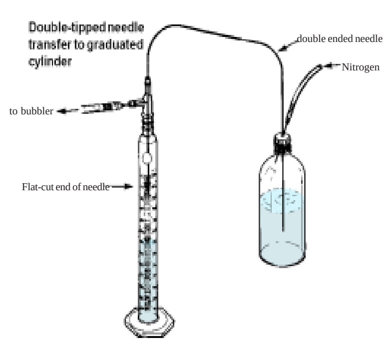


Fig. 3B Double-tipped needle transfer to graduated cylinder

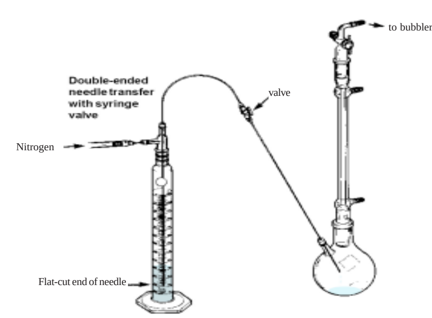


Fig. 3C Double-ended needle transfer with syringe valve

Storage

- Pyrophoric chemicals should be stored under an atmosphere of inert gas or under kerosene as appropriate.
- Avoid areas with heat/flames, oxidizers, and water sources.
- Containers carrying pyrophoric materials must be clearly labeled with the correct chemical name and hazard warning.
- For storage prepare a storage vessel with a septum filled with an inert gas
    - Select a septum that fits snugly into the neck of the vessel
    - Dry any new empty containers thoroughly
    - Insert septum into neck in a way that prevents atmosphere from entering the clean dry (or reagent filled) flask.
    - Insert a needle to vent the flask and quickly inject inert gas through a second needle to maintain a blanket of dry inert gas above the reactive reagent.

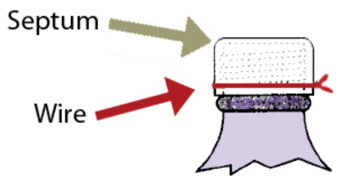


Fig. 4A Septa wired to vessel

    - Once the vessel is fully purged with inert gas, remove the vent needle then the gas line.
- For long-term storage, the septum should be secured with a copper wire **(figure 4A).**

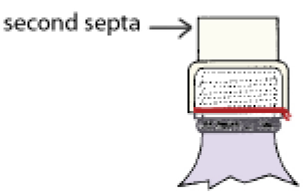


Fig. 4B For long-term storage, use a second septa

- For extra protection a second same-sized septa (sans holes) can be placed over the first **(figure 4b)**.
- Use parafilm around the outer septa and (obviously) remove the parafilm and outer septa before accessing the reagent through the primary septa

Disposal of Pyrophoric Reagents

- A container with any residue of pyrophoric materials should never be left open to the atmosphere.
- Any unused or unwanted pyrophoric materials must be destroyed by transferring the materials to an appropriate reaction flask for hydrolysis and/or neutralization with adequate cooling.
- The essentially empty container should be rinsed three times with an inert dry solvent; this rinse solvent must also be neutralized or hydrolyzed.
- After the container is triple-rinsed, it should be left open in back of a hood or atmosphere at a safe location for at least a week. After the week, the container should then be rinsed 3 times again.

Disposal of Pyrophoric Contaminated Materials

- All materials that are contaminated with pyrophoric chemicals should be disposed of as hazardous waste.
- Alert EH&S for any wastes contaminated by pyrophoric chemicals.
- The contaminated waste should not be left overnight in the open laboratory but must be properly contained to prevent fires.

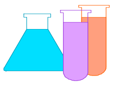
Emergency Procedures

Spill

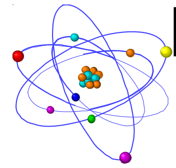
- Powdered lime should be used to completely smother and cover any spill that occurs.
- A container of powdered lime should be kept within arm's length when working with a pyrophoric material.
- If anyone is exposed, or on fire, wash with copious amounts of water.
- The recommended fire extinguisher is a standard dry powder (ABC) type. Class D extinguishers are recommended for combustible solid metal fires (e.g, sodium, LAH), but not for organolithium reagents.
- Call 9-911 for emergency assistance

---

[1] Created from a variety of resources, principally the Sigma-Aldrich Technical Bulletins and these websites: www.safety.rochester.edu/ih/standops8.html & www.brandeis.edu/ehs/labs/pyrophoric.html another good resource is Advanced Practical Organic Chemistry by J. Leonard, B. Lygo, and G. Procter esp. pages 76-98
Another good resource is this article from the American Chemical Society.
[2] Private communication to Rebecca Lally (rrlally@uci.edu) at UC Irvine in January 2009
[3] Images and advice from Sigma-Aldrich Technical Bulletins AL-134 and AL-164 at: http://www.sigmaaldrich.com/chemistry/aldrich-chemistry/tech-bulletins/tech-bulletin-numbers.html



LABORATORY SAFETY FACT SHEET #37



Safe Use of Pyrophoric/ Water Reactive Reagents

Introduction: Pyrophoric and water reactive materials can ignite spontaneously on contact with air, moisture in the air, oxygen, or water. Failure to follow proper handling procedures can result in fire or explosion, leading to serious injuries, death and/or significant damage to facilities. This fact sheet describes the hazards, proper handling, disposal and emergency procedures for working with pyrophoric and water reactives.

Any handling of a pyrophor/water reactive material is high risk and must be controlled with adequate system design, direct supervision and training. These tasks are two person tasks and workers should not work alone.

Examples of Pyrophoric/Water Reactive Materials

- Grignard Reagents: RMgX (R=alkyl, X=halogen)
- Metal alkyls and aryls: Alkyl lithium compounds; tert-butyl lithium
- Metal carbonyls: Lithium carbonyl, nickel tetracarbonyl
- Metal powders (finely divided): Cobalt, iron, zinc, zirconium
- Metal hydrides: Sodium hydride, lithium aluminum hydride
- Nonmetal hydrides: Diethylarsine, diethylphosphine
- Non-metal alkyls: R_3B, R_3P, R_3As; tetramethyl silane, tributyl phosphine
- White and red phosphorus
- Group I (Alkali) metals: Lithium, potassium, sodium, sodium-potassium alloy (NaK), rubidium, cesium, francium
- Gases: Silane, dichlorosilane, diborane, phosphine, arsine

Hazards: Because these reagents ignite on contact with air and/or water, they must be handled under an inert atmosphere and in such a way that rigorously excludes air/moisture. Some are toxic and many come dissolved or immersed in a flammable solvent. Other common hazards include corrosivity, teratogenicity, water reactivity, or peroxide formation, and may damage to the liver, kidneys, and central nervous system.

Controlling the Hazards: BEFORE working with pyrophoric or water reactive reagents, read the relevant Material Safety Data Sheets (MSDS), technical bulletins, and guidance documents to understand how to mitigate the hazards. The MSDS must be reviewed before using an unfamiliar chemical and periodically as a reminder. Users of reactive materials must be trained in proper lab technique and be able to demonstrate proficiency. Do not work alone or during off hours, when there are few people around to help. ALWAYS wear the appropriate personal protective equipment.

Remove all excess and nonessential chemicals and equipment from the fume hood or glove box where pyrophoric or water reactive chemicals will be used. This will minimize the risk if a fire should occur. Keep combustible materials, including paper towels and Kimwipes, away from reactive reagents.

Keep the amount of pyrophoric or water reactive material present in your lab to the smallest amount practical. Use and handle the smallest quantity practical. It is better to do multiple transfers of small volumes than attempt to handle larger quantities (greater than about 20 mL). Alternatively, an appropriately engineered system, capable of safely handling the larger quantity must be designed, tested and properly used.

Personal Protective Equipment (PPE)

Eye Protection

- A full face shield that meet the ANSI Z.87.1 1989 standard must be worn whenever handling pyrophoric chemicals (should have "Z87" stamp on it). Prescription eye glasses, safety glasses, and splash goggles will NOT provide adequate protection. A face shield, worn over safety eyewear, is required any time there is a risk of explosion, splash hazard or a highly exothermic reaction.
- All manipulations of pyrophoric chemicals which pose these risks must be carried out in a fume hood with the sash in the lowest feasible position.

Skin Protection

- In general, chemical protective gloves are unacceptable when working with pyrophors. If the reactive material were to ignite and spill onto the hand, nitrile or latex gloves would also ignite and contribute to serious injury.
- Nomex and related aramid fiber products are excellent fire retardant, but can significantly reduce dexterity. A Nomex flight glove (used by pilots to protect from heat and flash) works well.
- ***A fire retardant lab coat must be worn.*** Special fire-resistant lab coats made from Nomex or other fire resistant materials are more expensive, but recommended for labs using these reagents routinely. Lab coats need to be buttoned and fit properly to cover as much skin as possible.Clothing, shirt and pants, should be cotton or wool. **<u>Synthetic clothing is strongly discouraged</u>**.
- Appropriate shoes that cover the entire foot (closed toe, closed heel, no holes in the top) must be worn.

Safety Equipment: Researchers working with reactive materials must have the proper equipment and the emergency phone number (9-911) readily available for any emergencies, prior to starting research activities. Acceptable extinguishing media include soda ash (lime) or *dry* sand to respond to fires. DO NOT use water to attempt to extinguish a pyrophoric/reactive material fire as it can actually enhance the combustion of some of these materials, e.g. metal compounds. A small beaker of dry sand or soda ash (lime) in the work area is useful to extinguish any small fire that occurs at the syringe tip and to receive any last drops of reagent from the syringe. Review the MSDS for the proper fire extinguisher to use with the given material.

Eyewash/ Safety Shower

- A combination eyewash/safety shower should be within 10 seconds travel time where reactive chemicals are used. Inside the laboratory is optimum.
- If a combination eyewash/safety shower is not available within the lab, an eyewash must be available (within 10 seconds travel distance) for immediate emergency use within the lab. Bottle type eyewash stations are not acceptable. A combination eyewash/shower must be available in the hallway or similar, within 10 seconds travel distance and accessible through only one door.

Fume Hood

- Many reactive chemicals release noxious or flammable gases upon decomposition and should be handled in a laboratory hood. In addition, some pyrophoric materials are stored under kerosene (or other flammable solvent), therefore the use of a fume hood (or glove box) is required to prevent the release of flammable vapors into the lab.

Glove (dry) box

- Inert atmosphere glove boxes are an excellent device for the safe handling of reactive materials. Glove boxes used for this purpose should be in good working order and the moisture and oxygen levels of the atmosphere should be confirmed prior to introduction of reactive compounds into the box. Continuous monitoring of oxygen and moisture is highly recommended. Also, take into account interactions between items in the glovebox (e.g., nitrogen is not an inert gas for lithium metal as the lithium is reduced violently to lithium nitride).

Gas Cabinets

- Storage of pyrophoric gases is described in the CA Fire Code, Chapter 41. Gas cabinets, with remote sensors and fire suppression equipment, are required.

- Gas flow, purge and exhaust systems should have redundant controls to prevent pyrophoric gas from igniting or exploding.

- Emergency back-up power should be provided for all electrical controls, alarms and safeguards associated with the pyrophoric gas storage and process systems.

Storage and Disposal

Storage

- Use and store minimal amounts of reactive chemicals. Do not store reactive chemicals with flammable materials or in a flammable liquids storage cabinet. Containers carrying reactive materials must be clearly labeled with the correct chemical name, in English, and hazard warning.

- Store reactive materials as recommended in the MSDS. An inert gas-filled desiccator or glove box are suitable storage locations for most materials.

- If pyrophoric or water reactive reagents are received in a specially designed shipping, storage or dispensing container (such as the Aldrich Sure/Seal packaging system) ensure that the integrity of that container is maintained.

- Ensure that sufficient protective solvent, oil, kerosene, or inert gas remains in the container while the material is stored.

- NEVER return excess chemical to the original container. Small amounts of impurities introduced into the container may cause a fire or explosion.

- For storage of excess chemical, prepare a storage vessel in the following manner:

    - Dry any new empty containers thoroughly

    - Insert the septum into the neck in a way that prevents atmosphere from entering the clean dry (or reagent filled) flask.

    - Insert a needle to vent the flask and quickly inject inert gas through a second needle to maintain a blanket of dry inert gas above the reagent.

- Once the vessel is fully purged with inert gas, remove the vent needle then the gas line. To introduce the excess chemical, use the procedure described in the handling section, below.
- For long-term storage, the septum should be secured with a copper wire (figure 1A).
- For extra protection a second same-sized septa (sans holes) can be placed over the first (figure 1B).
- Use parafilm around the outer septa and remove the parafilm and outer septum before accessing the reagent through the primary septum.

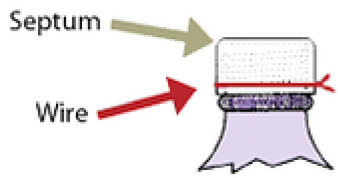


Fig. 1A Septum wired to vessel

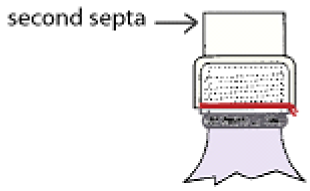


Fig. 1B For long-term storage, use a second septum

Disposal of Pyrophoric Reagents

- Any container with a residue of reactive materials should never be left open to the atmosphere.
- Any unused or unwanted reactive materials must be destroyed by transferring the materials to an appropriate reaction flask for hydrolysis and/or neutralization with adequate cooling.
- The empty container should be rinsed three times with an inert dry COMPATIBLE solvent; this rinse solvent must also be neutralized or hydrolyzed. The rinse solvent must be added to and removed from the container under an inert atmosphere.
- After the container is triple-rinsed, it should be left open in back of a hood or ambient atmosphere at a safe location for at least a week.
- The empty container, solvent rinses and water rinse should be disposed as hazardous waste and should not be mixed with incompatible waste streams.

Disposal of Pyrophoric or Water Reactive Contaminated Materials

- All materials – disposable gloves, wipers, bench paper, etc. - that are contaminated with pyrophoric chemicals should be disposed as hazardous waste. Proper and complete hazardous waste labeling of containers is vital.
- The contaminated waste should not be left overnight in the open laboratory but must be properly contained to prevent fires.

Important Steps to Follow: Reactive reagents can be handled and stored safely as long as all exposure to atmospheric oxygen and moisture or other incompatible chemicals is avoided. Finely divided solids must be transferred under an inert atmosphere in a glove box. Liquids may be safely transferred without the use of a glove box by employing techniques and equipment discussed in the Aldrich Technical Information Bulletin AL-134. Pyrophoric gases must be handled in compliance with the California Fire Code, Chapter 41. Another good reference is "Manipulation of Air-sensitive Compounds" by Shriver and Drezdzon.

The California Fire Code prohibits the storage or use of pyrophorics in buildings not fully protected by an automatic sprinkler system. If you are using a pyrophoric in an unsprinklered building contact EH&S at x-4899 immediately so that we may assist you with the options available to mitigate the situation.

Handling Pyrophoric Liquids

- Users should read and understand the Aldrich Technical Information Bulletin No. AL-134. The PI should also have in place laboratory-specific handling, storage, and disposal standard operating procedures. The standard operating procedures should be included in the lab Chemical Hygiene Plan.
- By using proper syringe techniques, these reagents can be handled safely in the laboratory. The Aldrich Sure/Seal™ Packaging System provides a convenient method for storing and dispensing air-sensitive reagents. Schlenk glassware is another suitable option.
- The reagent can be dispensed using a syringe or double-tipped needle (canula) (16, 18 or 20 gauge) inserted through the hole in the metal cap, as shown in fig. 2 below. It is recommended that the plastic cap be replaced after each use and in particular for long-term storage.

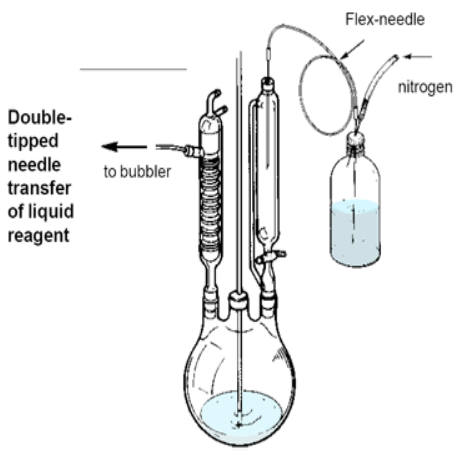


Fig. 2 Double-tipped needle transfer of liquid reagent

- For extended storage of unused reagents, use the solid plastic cap, or equip the bottle with an Oxford Sure/Seal valve cap, or transfer the reagent to a suitable storage vessel, as described above.

Emergency Procedures

Spill

- DO NOT use water to attempt to extinguish a reactive material fire as it can actually enhance the combustion of some reactive materials, e.g. metal compounds.
- Do not use combustible materials (paper towels) to clean up a spill, as these may increase the risk of igniting the reactive compound. Soda ash (powdered lime) or dry sand should be used to completely smother and cover any small spill that occurs.
- A container of soda ash (powdered lime) or dry sand should be kept within arm's length when working with a reactive material.
- If anyone is exposed, or on fire, wash with copious amounts of water, except if metal compounds are involved, which can react violently with water. In the case of a metal fire, smothering the fire is a better course of action.
- The recommended fire extinguisher is a standard dry powder (ABC) type. Class D extinguishers are recommended for combustible solid metal fires (e.g, sodium, LAH), but not for organolithium reagents.
- Call 9-1-1 for emergency assistance and for assistance with all fires, even if extinguished.
- Pyrophoric gas releases and associated fires, should be extinguished by remotely stopping the gas flow. NEVER ATTEMPT TO PUT OUT A GAS FIRE IF THE GAS IS FLOWING.

Sources and Acknowledgements:

Created from a variety of sources including: Brandeis University, Standard Operating Procedure for Pyorphoric Chemicals; University of Nebraska, Lincoln, Pyrophoric Chemicals Standard Operating Procedure; University of Pittsburgh Safety Manual, Flammable and Pyrophoric Gas; Rochester University, SOP for Pyrophoric Chemicals. Images from Sigma-Aldrich Technical Bulletins AL-134 and AL-164.

Personal communication with(and grateful acknowledgement to) Dr. Russell Vernon, Environmental Health and Safety, UC, Riverside; Dr. Joseph Pickel, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory; Dr. Neal Langerman, Principal, Advanced Chemical Safety, Inc.; Dr. Frank Osterloh, Professor of Chemistry, UC Davis.

Handling Pyrophoric Reagents

revised 6/95

Fig. 1 Pyrophoric reagents may be packed in a variety of containers.

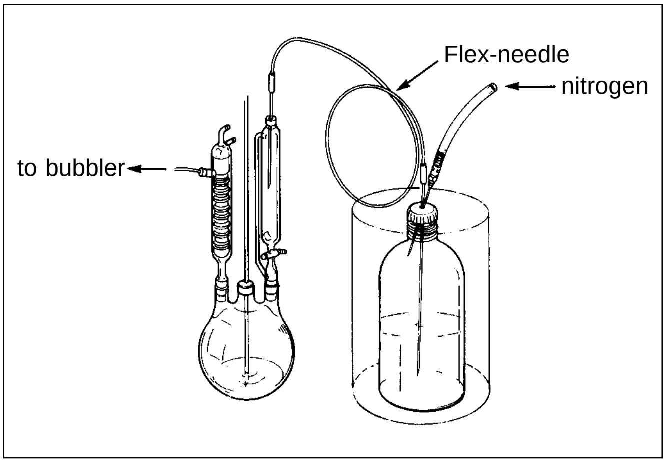


Fig. 2 Double-tipped needle transfer of pyrophoric liquid.

Fig. 3

Fig. 4

NOTE: The metal can in which each bottle is shipped should be retained as a protective container for transporting and storing the bottle of reagent.

I. INTRODUCTION AND PRECAUTION

Due to the hazardous nature of pyrophoric reagents, we strongly recommend that all users read this bulletin carefully and completely before starting any actual laboratory work. If you are unsure of any of these procedures or if you need assistance, please contact us prior to use.

All users of these reagents must be fully qualified and experienced laboratory workers to handle pyrophoric reagents without problems. All users must be made aware of the very hazardous nature of these products.

Users must have read and understood our Technical Information Bulletin No. AL-134 which describes standard syringe and double-tipped-needle transfer techniques before attempting to handle liquid pyrophoric reagents (see Fig. 2).

II. NATURE OF THE REAGENTS

Pyrophoric reagents are extremely reactive toward oxygen and in most cases, water, and must never be exposed to the atmosphere. Failure to follow proper handling techniques could result in serious injury. Exposure of these reagents to air could result in spontaneous combustion, which could cause serious burns or other injuries to the person handling the reagent or others in the immediate area.

In addition, all combustible materials, including paper products, should not be allowed to come in contact with any pyrophoric reagent at any time.

III. HANDLING

Pyrophoric reagents can be handled and stored safely as long as all exposure to atmospheric oxygen and moisture is avoided. Solids must be transferred under an inert atmosphere in an efficient glove box. Liquids may be safely transferred without the use of a glove box by employing techniques and equipment discussed in our Technical Information Bulletin AL-134.

Again, users must have read and understood the accompanying Technical Bulletin AL-134 (call us immediately for a copy if yours has been misplaced), before attempting to handle liquid pyrophoric reagents.

Glass bottles of pyrophoric reagents should not be handled or stored unprotected. The metal can shipped with each bottle should be retained as a protective container for each bottle for transporting and storage (see Fig. 3 and 4).

(OVER)

IV. SPILL

Powdered lime should be used to completely smother and cover any spill that occurs.

A container of powdered lime should be kept within arm's length when working with a pyrophoric material.

IV. DISPOSAL

We feel that the user of the reagent is the person most familiar with the contents and should accept the responsibility for safe disposal of the empty container.

A container with any residual material **MUST NEVER** be opened to the atmosphere. The last traces of reagent must be removed and should be used completely for a chemical reaction; however, if unused and unwanted material must be destroyed, it must be transferred to an appropriate reaction flask for hydrolysis and/or neutralization with adequate cooling.

The essentially empty container is then rinsed three times with an inert dry solvent; this rinse solvent must also be neutralized or hydrolyzed. The solvent must be added to and removed from the container under an inert atmosphere. After adding each rinse, the container is swirled or shaken. The best solvent to use is the same solvent used for the solution of the original reagent. If the container originally contained a **neat reagent, then use a solvent which is completely inert and unreactive toward the reagent.**

After the triple rinse is complete, the container is opened to the atmosphere at a safe location, preferably outdoors or, AT A MINIMUM, IN THE BACK OF A HOOD. After allowing the container to be exposed to the atmosphere for at least a week, the container must be triple-rinsed with water before disposal.

This hazard sheet must remain with the container at all times. If you have any questions, please contact us.

Aldrich Chemical Company, Inc.

1001 West Saint Paul Ave., Milwaukee, WI 53233
Telephone 414-273-3850 / 800-231-8327
Fax 414-273-4979 / 800-962-9591
Internet INFO@ALDRICH.COM
TWX 910-262-3052

SIGMA-ALDRICH®

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Technical Bulletin AL-134

Handling Air-Sensitive Reagents

The Aldrich® Sure/Seal™ system

Anhydrous solvents and air-sensitive reagents from Aldrich are packaged in our exclusive Sure/Seal bottles which provide a convenient method for storing and dispensing research quantities of these products. With this bottle, reactive materials can be handled and stored without exposure to atmospheric moisture or oxygen. The reagent comes in contact only with glass and a specially designed resin layer, yet it can be readily transferred using standard syringe techniques.

The polypropylene cap on a Sure/Seal bottle can be safely removed because the crown cap and liner are already crimped in place. The reagent can then be dispensed using a syringe or double-tipped needle inserted through the hole in the metal cap (**Fig.1**). We recommend only small-gauge needles (no larger than 18-gauge) be used and the polypropylene cap be replaced after each use. After the needle has been withdrawn from the bottle, the new elastomer liner provides outstanding resealing properties to protect the contents within from moisture and oxygen in the atmosphere.

Fig. 1 Crown cap with hole

Equipment Overview

Reactions involving our air-sensitive reagents can be carried out in common ground-glass apparatus. Other equipment required are a source of inert gas, a septum inlet, a bubbler, and syringes fitted with suitable needles.

Glassware preparation

Laboratory glassware contains a thin film of adsorbed moisture which can be easily removed by heating in an oven (125 °F/overnight or 140 °F/4 hrs). The hot glassware should be cooled in an inert atmosphere by assembling the glassware while hot and flushing with a stream of dry nitrogen or argon. A thin film of silicone or hydrocarbon grease must be used on all standard-taper joints to prevent seizure upon cooling. Alternatively, the apparatus may be assembled cold and then warmed with a heat gun while flushing with dry nitrogen. The oven-drying procedure is more efficient than using a heat gun because it removes moisture from inner surfaces of condensers and from other intricate parts.

Most of the techniques described in this bulletin were developed for handling various organoborane reagents. However, these methods are applicable to other air-sensitive solvents and reagents on a preparative laboratory scale.

Contents

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Inert gas supply and flushing equipment

Joint clips are required to secure joints during flushing since the nitrogen pressure may open the seals of unsecured standard-taper joints. Only high-purity, dry nitrogen from a cylinder with a pressure regulator (adjusted to 3-5 psi) should be used for flushing. Plastic tubing can be used to connect the nitrogen line to a tube connector adapter (equipped with a stopcock) on the reaction apparatus. Nitrogen may also be introduced through a rubber septum via a hypodermic needle connected to the end of the flexible tubing on the nitrogen line. The needle-tubing connector provides a simple method for attaching the needle to the tubing. When not in use, this nitrogen-flushing needle should be closed by inserting the needle into a solid rubber stopper or septa to prevent diffusion of air into the needle when the nitrogen is turned off (**Fig.2**).

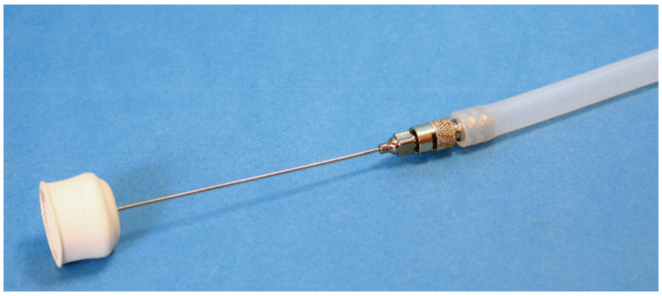


Fig. 2. Nitrogen-flushing needle

Septum inlet glassware

Large rubber septa may be used to cap female joints. However, the use of 6 mm septa and 9 mm o.d./6 mm i.d. medium-wall glass septum inlets is preferred. The small rubber septum provides a more positive reseal after puncture and allows less rubber to be in contact with organic vapors in the reaction vessel. With the recommended medium-wall tubing, the 6 mm septum not only fits the inside diameter of the glass tube but also fits snugly over the outside when the top is folded over (**Fig. 3**). The glass septum inlet can be built into the reaction flask (**Fig. 4**) or placed on an adapter (**Fig. 5**) for use with unmodified glassware. The rubber septum may be secured in place as shown in **Fig. 3**. with a nylon Wrap-it Tie. However, if the 6 mm septum is properly fitted to 9 mm medium-wall tubing, the ties may not be needed unless high pressures (>10 psi) are expected.

Fig. 3a Fig. 3b Fig. 3c

Fig. 3. Use of septum inlet

Fig. 4. Flask with septum inlet

Bubblers for pressure equalization

To maintain an air-tight system the reaction vessel must be vented through a mercury or mineral oil bubbler. Drying tubes will not prevent oxygen from entering the system. At all times during the reaction, the system should be under a slight positive pressure of nitrogen as visually indicated by the bubbler. **Fig. 6** illustrates a suitable bubbler. A pressure reversal may cause the liquid in the bubbler to be drawn into the reaction vessel. The enlarged head space in the bubbler will minimize this danger. However, if a large pressure reversal occurs, air will be admitted into the reaction vessel. The T-tube bubbler shown can be used to prevent this problem because nitrogen pressure can be introduced intermittently through the septum inlet. The problem can be completely eliminated by a slow and continuous nitrogen flow.

Fig. 5 Septum inlet adapter

Syringe transfer tips

Small quantities (up to 50 mL) of air-sensitive reagents and dry solvents may be transferred with a syringe equipped with a 1-2 ft long needle. These needles are used to avoid having to tip reagent bottles and storage flasks. Tipping often causes the liquid to come in contact with the septum causing swelling and deterioration of the septa, and should therefore be avoided.

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

A rubber septum provides a positive seal for only a limited number of punctures depending on the needle size. Therefore, always reinsert the needle through the existing hole. It is also advantageous to put a layer of silicone or hydrocarbon grease on a rubber septum to facilitate passage of the needle through the rubber and to minimize the size of the hole in the septum.

Syringe/needle preparation

Ideally, the syringe and needle should be dried in an oven prior to use. Naturally, the syringe body and plunger should not be assembled before being placed in the oven. The syringe should be flushed with nitrogen during the cooling. A syringe may also be flushed 10 or more times with dry nitrogen (**Fig. 7**) to remove the air and most of the water adsorbed on the glass. A dry syringe may be closed to the atmosphere by inserting the tip of the needle into a rubber stopper or septa. (**Fig 2**). The syringe-needle assembly should be tested for leaks prior to use. The syringe is half-filled with nitrogen and the needle tip is inserted in a rubber stopper. It should be possible to compress the gas to half its original volume without any evidence of a leak. A small amount of stopcock grease or a drop of silicone oil placed on the Luer lock tip will help ensure tightness.

Reagent transfer with syringe

The syringe transfer of liquid reagents (up to 100 mL) is readily accomplished by first pressurizing the Sure/Seal™ reagent bottle with dry, high-purity nitrogen followed by filling the syringe (**Fig. 8**).

1. The nitrogen pressure is used to slowly fill the syringe with the desired volume plus a slight excess (to compensate for gas bubbles) of the reagent. Note the nitrogen pressure pushes the plunger back as the reagent enters the syringe. The plunger should not be pulled back since this tends to cause leaks and create gas bubbles.
2. The excess reagent along with any gas bubbles is forced back into the reagent bottle (**Fig. 9**).
3. The accurately measured volume of reagent in the syringe is quickly transferred to the reaction apparatus by puncturing a rubber septum on the reaction flask or addition funnel (**Fig. 10**). **Note:** larger syringes are available but are awkward to handle when completely full.

Reagent transfer with a double-tipped needle

To conveniently transfer 50 mL or more of reagent, the double-tipped needle technique is recommended. **Fig. 11** illustrates liquid-reagent transfer under nitrogen pressure using this technique.

1. To accomplish the double-tipped needle transfer, the needle is first flushed with nitrogen.
2. The Sure/Seal bottle is pressurized with nitrogen using the nitrogen flushing needle.
3. The double-tipped needle is then inserted through the septum on the reagent bottle into the head space above the reagent. Nitrogen immediately passes through the needle. Finally, the

Fig. 6 Bubbler

Fig. 7 Flushing a syringe with nitrogen

Fig. 7a

Fig. 7b

Fig. 8 Filling syringe using nitrogen pressure

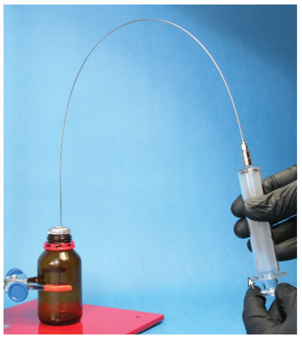


Fig. 9 Removing gas bubbles and returning excess reagent to the Sure/Seal bottle

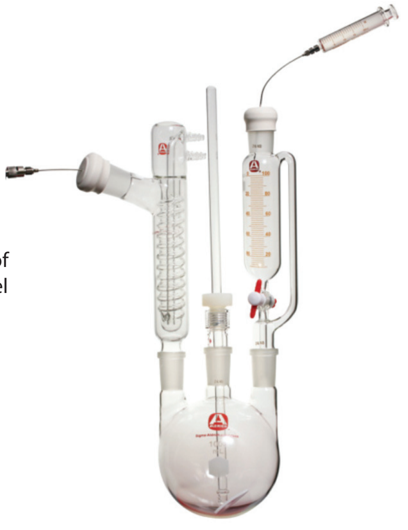


Fig. 10 Syringe transfer of reagent to reaction vessel

other end of the double-tipped needle is inserted through the septum on the reaction apparatus, and the end of the needle in the reagent bottle is pushed down into the liquid. The volume of liquid reagent transferred is measured by using a calibrated flask or addition funnel. When the desired volume has been transferred, the needle is immediately withdrawn to the head space above the liquid, flushed slightly with nitrogen, and removed. The needle is first removed from the reaction apparatus and then from the reagent bottle.

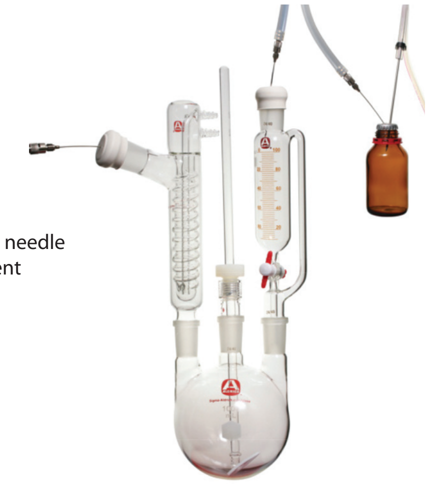


Fig. 11 Double-tipped needle transfer of liquid reagent

An alternative method

Transferring measured amounts of reagents (**Fig. 12**).

1. The reagent is first transferred via a double-ended needle from the Sure/Seal bottle to a dry, nitrogen-flushed graduated cylinder (**Fig. 13**) equipped with female joint and a double inlet adapter. Only the desired amount of reagent is transferred to the cylinder.
2. The needle is then removed from the Sure/Seal bottle and inserted through the septum on the reaction apparatus. By applying nitrogen pressure as before, the reagent is added to the reaction apparatus.

If it is necessary to add the reagent slowly, a modified transfer needle is constructed from two long standard needles and a male Luer lock to male Luer lock syringe valve. The valve may be opened slightly allowing only a very slow flow of reagent. Thus, the addition funnel is not needed and many reactions can be carried out in single-necked flasks (**Fig. 13**).

Fig. 12 Double-tipped needle transfer to graduated cylinder

Fig. 13 Double-ended needle transfer with syringe valve

Storage vessels

The 12-gauge stainless steel needles on the Chem-*Flex*™ transfer line provide a rapid means of transferring air-sensitive reagents under nitrogen pressure. However, the needles are so large that once the crown cap liner on the Sure/Seal bottle is punctured, the liner may not self-seal. If only a portion of the contents is to be used, a needle no larger than 16-gauge should be utilized. By using small needles the reagent in a Sure/Seal bottle will not deteriorate even after numerous septum punctures.

However, if the reagent is to be used repeatedly for small scale reactions or if an unused portion is to be stored for an extended length of time, the material should be transferred from the Sure/Seal bottle to a suitable storage vessel.

One type of vessel is the Sure/Stor™ flask for air-sensitive reagents (**Fig. 14**). Alternatively, an appropriate adapter can be used to convert a round-bottomed flask into a storage vessel (**Fig. 15**).

The PTFE valve on the storage vessel keeps solvent vapors away from the septum, thereby minimizing swelling and deterioration of the septum. Furthermore, the valve allows for replacement of the septa. A change of septa is sometimes necessary because they tend to deteriorate on prolonged standing in a laboratory atmosphere.

Fig. 14 Aldrich Sure/Stor™ flask

Fig. 15 Aldrich Sure/Stor™ adapter

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Equipment cleanup

Clean-up of equipment that has been used to transfer air-sensitive reagents must not be taken lightly. Since many of these reagents react violently with water, fires are a potential hazard.

Empty Sure/Seal bottles – the crown cap and liner of an empty Sure/Seal bottle should be carefully removed and the open bottle left in the hood to allow the last traces of reactive reagent to be slowly air-hydrolyzed and oxidized. After at least a day, the inorganic residue can be rinsed out with water. Empty storage bottles and storage flasks should be treated similarly. Air-hydrolysis in a hood is appropriate only for the last traces of material that remain after a Sure/Seal bottle has been emptied as completely as possible via syringe or double-ended needle transfer. The Aldrich Catalog/Handbook or material safety data sheets should be consulted for the recommended disposal procedures for larger amounts of reactive chemicals.

Syringes and needles – Immediately clean all syringes and needles that have been used to transfer air-sensitive materials. Also, in general, a syringe should only be used for a single transfer. Failure to follow this practice can result in plugged needles and frozen syringes due to hydrolysis or oxidation of the reagents. The double-tipped needles are flushed free of reagent with nitrogen in the transfer system, and then immediately removed and placed in a clean sink. With water running in the sink and in the complete absence of flammable solvents and vapors, the double-tipped needles or Chem-Flex needle can be rinsed with water. When no activity in the rinse water is observed, acetone from a squeeze bottle can be flushed through the needle. Depending on the reagent transferred, it may be necessary to use dilute acid or base from a squeeze bottle to remove inorganic residue that is not water-soluble.

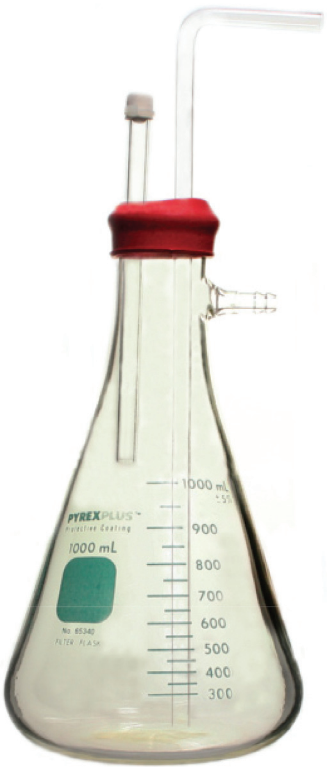


Fig. 16 Needle cleaning and drying technique

Following its use, a syringe contains a larger amount of residual reagent. It is advisable to rinse out the reactive reagent by first placing a few milliliters of the same solvent that was used for the reagent in a small Erlenmeyer flask in the hood. Keeping the needle tip under the solvent at all times, no more than half the solvent is then drawn into the syringe. The solvent plus dissolved residual reagent is ejected from the syringe back into the same Erlenmeyer flask. Repeat this rinse treatment at least three times. The wash solution can be safely combined with other waste solvents and the syringe may be further cleaned with water and acetone in the sink. Again, treatment with dilute aqueous acid or base may be necessary.

Once the syringe needles and double-tipped needles have been rinsed in a sink, they can be further cleaned and dried using a device similar to that shown in **Fig. 16**. Needles are cleaned by inserting them through the septum. Vacuum from a water aspirator is used to pull solvents from squeeze bottles through the needles. After pulling air through the system for a few minutes, the syringe plus needle or double-tipped needle will be dry. The syringe plunger should be replaced in the barrel for storage. If a syringe plunger and barrel are not assembled for storage, dust can settle on the plunger and in the barrel. Upon reassembly, these fine particles will occasionally scratch the barrel or cause seizure of the plunger on the barrel. However, the plunger and barrel must be disassembled before oven drying.

Summary

When handling air-sensitive materials, be prepared for the unexpected. For example, at least one extra set of clean, dry syringes and needles or double-tipped needles should always be available in case the first set of equipment becomes plugged. When working with these air-sensitive reagents keep in mind that these solutions should never be allowed to come in contact with the atmosphere.

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Labware for Handling Air-Sensitive Solvents and Reagents

A wide range of Labware products are available from Sigma-Aldrich for performing the techniques referenced in this technical bulletin. A sampling of these products are listed below. For additional products and ordering information, see the Sigma-Aldrich Labware Catalog or visit our website at sigma-aldrich.com/labware.

BUBBLERS

For safe pressure equalization during material transfers or reactions.

In-line bubbler

Use with oil or mercury, 5-7 mL. For monitoring gas evolution rate or rate of flow, or for closing off a reaction vessel from the atmosphere.
Cat. No. Z101214

In-line bubbler

SYRINGES, FITTINGS, AND NEEDLES

For transferring air-sensitive solvents and reagents.

Micro-Mate™ hypodermic syringes

Made from borosilicate glass with chrome-plated brass metal parts. Interchangeable barrels and plungers. All have needle-lock Luer tips. Additional sizes and tip styles are available.

Cat. No.	Capacity (mL)	Graduated (mL)
Z101052	5	0.2
Z101060	10	0.2
Z101079	20	1.0
Z101087	30	1.0
Z102342	50	2.0

Micro-Mate hypodermic syringes

All polypropylene Luer lock syringes

Non-contaminating, sterile, disposable syringes with safety stop to prevent plunger separation. Individually peel-packed.

Cat. No.	Capacity (mL)	Graduated (mL)
Z248002	3	0.1
Z248010	5	0.2
Z248029	10	0.5
Z248037	20	1.0

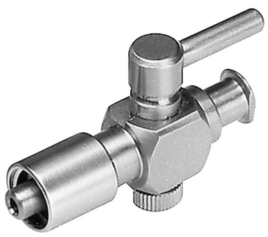
Polypropylene Luer lock syringes

Perfektum® one-way compression-nut stopcock

Additional stopcock types are available.

Female Luer to male Luer lock, not unidirectional.
Cat. No. Z102350

Male Luer lock to male Luer lock, not unidirectional.
Cat. No. Z102377



Perfektum one-way compression-nut stopcock (female to male)

Syringe needles with noncoring point

304 stainless steel, chrome-plated brass Luer hub, 18 gauge. Additional lengths and gauges are available.

Cat. No.	L (in.)
Z102717	6
Z117102	10
Z101141	12
Z100862	24

Stainless steel 304 syringe needles

Double-tipped transfer needles

304 stainless steel with a noncoring point on both ends. Additional lengths and gauges are available.

Cat. No.	L (in.)	Gauge
Z175595	12	20
Z101095	24	20
Z100889	24	18
Z100897	24	16
Z185221	24	14
Z185213	24	12
Z100900	36	16
Z185205	36	12

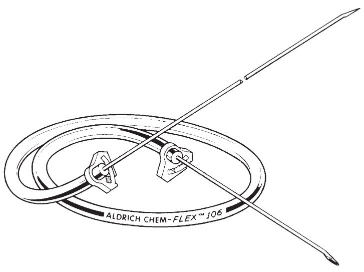
Double-tipped transfer needles

Chem-FLEX™ transfer lines

Two 12 gauge needles (6 and 18 in.) are connected to the Chem-FLEX 106 tubing with clamps. Liquids contact only PTFE and stainless steel during transfers.

Cat. No.	Tubing L (in.)
Z231029	30
Z281751	60
Z281778	120

Chem-FLEX transfer lines



INERT GAS SAFETY REGULATORS

For pressure transfer and purging operations.

The most compact laboratory regulator available. The bonnet is labeled "Inert Gas" to identify use. Outlet needle valve with ¼ inch NPTM connection. CGA 580 inlet.
Cat. No. Z569054

Inert gas regulator

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

RUBBER SEPTA

Additional septa sizes and types are available.

Red

Cat. No.	Size
Z565687	8 mm OD tubing
Z565709	9-10 mm OD tubing
Z554073	14/20 joints
Z554103	24/40 joints
Z554111	29/42 joints

Rubber septa

White

Cat. No.	Size
Z565695	8 mm OD tubing
Z565717	9-10 mm OD tubing
Z553964	14/20 joints
Z553980	24/40 joints
Z553999	29/42 joints

Reaction tube

SCHLENK TYPE GLASSWARE

Designed specifically for air-sensitive chemical reactions.

Reaction tubes

2 mm glass stopcock with 14/20 joint.

Cat. No.	Capacity (mL)
Z409235	10
Z409243	25
Z409251	50
Z409278	100
Z409286	250

Septum-inlet adapters

SEPTUM INLET ADAPTERS AND FLASKS

Small bore inlets for syringe transfers.

Septum-inlet adapters

Additional adapter styles are available.

Cat. No.	Stopcock	Joint
Z107387	Glass	14/20
Z107409	Glass	24/40
Z102288	PTFE	14/20
Z101370	PTFE	24/40

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Septum-inlet flasks

Glass stopcock with 14/20 joint. Additional capacities and joint sizes are available.

Cat. No.	Capacity (mL)
Z515868	25
Z515876	50
Z515884	100
Z515914	250

Septum-inlet flasks

STORAGE BOTTLES AND FLASKS

For long-term storage of solvents and reagents.

Sure/Stor™ flasks

Designed for safe, reliable storage and dispensing of air-sensitive and odoriferous chemicals, pyrophorics, alkyl lithiums, Grignards, corrosives, and purified or deuterated solvents. High-vacuum PTFE valve. Additional flasks sizes, amberized, and plastic-coated glass are available.

Cat. No.	Capacity (mL)
Z404977	25
Z404985	50
Z404993	100
Z405000	250

Sure/Stor flasks

Storage bottles

Clear glass with PTFE stopcock and septum inlets.

Cat. No.	Capacity (mL)
Z103284	125
Z103292	250
Z101990	500
Z102482	1,000
Z103306	2,000

Storage bottles

This page intentionally left blank

FEATURE

Safe handling of organolithium compounds in the laboratory

Organolithium compounds are extremely useful reagents in organic synthesis and as initiators in anionic polymerizations. These reagents are corrosive, flammable, and in certain cases, pyrophoric. Careful planning prior to execution of the experiment will minimize hazards to personnel and the physical plant. The proper personal protective equipment (PPE) for handling organolithium compounds will be identified. Procedures to minimize contact with air and moisture will be presented. Solutions of organolithium compounds can be safely transferred from the storage bottles to the reaction flask with either a syringe or a cannula. With the utilization of these basic techniques, organolithium compounds can be safely handled in the laboratory.

By James A. Schwindeman, Chris J. Woltermann, and Robert J. Letchford

INTRODUCTION

When properly handled, organolithiums provide unique properties that allow for more precise control and greater performance features. With proper care and attention, organolithiums can be safely and effectively utilized in both laboratory and physical plant environments, while being the effective choice for many synthesis applications. Organolithium compounds fall into four broad categories: alkyllithiums (exemplified by *n*-butyllithium), aryllithiums (such as phenyllithium), lithium amides (for example, lithium diisopropylamide and lithium hexamethyldisilazide) and lithium alkoxides (typified by lithium *t*-butoxide). These organolithium compounds have found wide utility as reagents for organic synthesis in a variety of applications. For example, they can be employed as strong bases (alkyllithiums, aryllithiums, lithium amides and lithium alkoxides), nucleophiles (alkyllithium and aryllithium compounds) and reagents for metal–halogen exchange (alkyllithium and aryllithium compounds).[1] Alkyllithium compounds have also found extensive application as initiators for anionic polymerization. The unique properties of the carbon–lithium bond in polymerization processes allow the precise control of the polymer's molecular architecture.[2]

James A. Schwindeman *received his B.S. degree in Chemistry from Miami University and his Ph.D. in Organic Chemistry from the Ohio State University, has over 10 years experience in the synthesis of organometallic compounds at FMC Lithium.*
E-mail: jim_schwindeman@fmc.com.
Chris J. Woltermann *received his B.S. in Chemistry from the University of Dayton in 1990 and his Ph.D. in Organic Chemistry from the Ohio State University in 1996.*
Robert J. Letchford *received his B.S. degree in Chemical Engineering from Youngstown State University and a M.S. degree in Polymer Chemistry from the University of Akron.*

CHARACTERISTICS OF ORGANOLITHIUM COMPOUNDS

Several characteristics of organolithium compounds have enhanced their utilization in the laboratory. First, organolithium compounds exhibit excellent solubility in organic solvents. As an example, *n*-butyllithium is available commercially as a solution in hexanes from 1.5 M (15 wt.%) to 10 M (85 wt.%). One caveat is that alkyllithium compounds do react with ethereal solvents.[3] Second, in contrast to alkylorganometallics derived from other alkali metals, alkyllithium compounds have enhanced stability.[4] The alkyllithium compounds exhibit sufficient stability to be prepared, stored and transported. Third, a wide range of base strength is available from the various classes of organolithium compounds, with pK_a from 15.2 (lithium methoxide) to 53 (*t*-butyllithium).[5] Fourth, organolithium reagents demonstrate enhanced nucleophilicity compared to the corresponding organomagnesium compound. Finally, they are convenient, as a variety of organolithium compounds from all four categories are commercially available. Thus, the experimentalist can select and purchase the appropriate reagent needed for the desired transformation.

HAZARDS OF ORGANOLITHIUM COMPOUNDS

Organolithium compounds, which exhibit outstanding performance in a variety of applications, are highly reactive materials. There are three principal hazards associated with these compounds: corrosivity, flammability and, in certain instances, pyrophoricity. The inherent corrosive nature of all four classes of organolithiums can cause chemical and thermal burns upon operator exposure. The organolithium compounds themselves are flammable. Typically, they are supplied in an organic solvent, which exacerbates the flammability. Pyrophoricity[6] is defined as the property of a material to spontaneously ignite on exposure to air, oxygen or moisture. In particular, all formulations of *n*-butyllithium, *s*-butyllithium and *t*-butyllithium are pyrophoric, as determined by the official Department of Transportation (DOT) protocol.[7] Before any laboratory work with an organolithium is conducted,

1074-9098/02/$22.00
PII S1074-9098(02)00295-2

appropriate planning should be conducted to safeguard personnel and property against these hazards.

There are a number of factors that influence the pyrophoric nature of the alkyllithium compound. For the same concentration of alkyllithium, the pyrophoricity increases in the order *n*-butyllithium < *s*-butyllithium < *t*-butyllithium. For a given alkyllithium, the pyrophoricity also increases as the concentration of the alkyllithium increases in the formulation. The solvent in the formulation also influences pyrophoricity. The lower the flash point of the solvent the greater the pyrophoricity. Pyrophoricity is also impacted by environmental factors in the laboratory. Higher relative humidity and higher ambient temperature result in greater pyrophoricity.[8]

The stability of two classes of organolithium compounds must also be considered. Alkyllithium compounds undergo thermal decomposition *via* loss of lithium hydride, with formation of the corresponding alkene. The decomposition of *n*-butyllithium is illustrated in Figure 1.

Several factors influence the rate of this decomposition. The thermal stability of alkyllithiums increases in the series *s*-butyllithium < *n*-butyllithium < *t*-butyllithium, at the same concentration.[9] For a given alkyllithium, the stability increases with decreasing concentration in the formulation.[9] A lower storage temperature lowers the decomposition rate. The presence of alkoxide impurities, generated from admission of adventious oxygen, accelerates the rate of decomposition.[10] Lithium dialkylamides also undergo decomposition *via* loss of lithium hydride, to afford the corresponding imine. The decomposition of lithium diisopropylamide is illustrated in Figure 2. The rate of this decomposition is primarily impacted by the storage temperature. Higher temperature accelerates the decomposition. The lithium hydride that is produced in the decomposition of alkyllithium compounds and lithium dialkylamides precipitates from the solution as very fine particles. This finely divided lithium hydride is pyrophoric. To maximize the shelf-life of these materials, it is recommended that they be stored in an explosion-proof refrigerator at <10°C. Further, since the assay of these reagents can decline with storage, it is good practice to verify the assay prior to utilization in an experiment.[11]

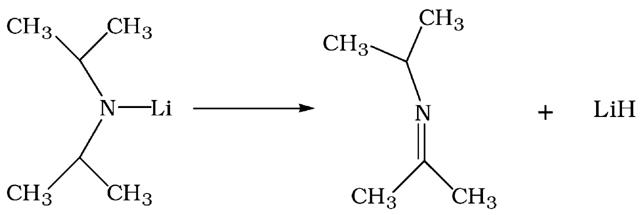


Figure 2. Thermal decomposition of lithium diisopropylamide.

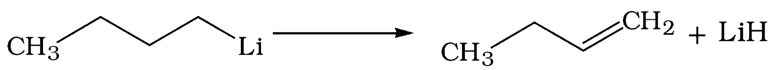


Figure 1. Thermal decomposition of *n*-butyllithium.

PLANNING THE EXPERIMENT

In spite of these hazards, the reactivity of organolithium compounds has been successfully harnessed. Indeed, with proper planning on the part of the experimenter, organolithium compounds can be safely handled in the laboratory. These same techniques can also be employed in large-scale applications, from kilo laboratory up to commercial-scale production. Proper precautions must be taken against the principle hazards of organolithium compounds: corrosivity, flammability and in certain instances, pyrophoricity. There are a number of circumstances that must be avoided in dealing with organolithium compounds in the laboratory: personnel exposure, air, oxygen, moisture, water, heat, clutter, source of ignition (spark) and fuel. Prior to the commencement of an experiment that utilizes an organolithium, it is strongly recommended to consult the Material Safety Data Sheet (MSDS) supplied by the vendor. The MSDS will contain recommendations for handling and storage of the specific organolithium compound of interest.

The first consideration in planning the experiment is location–where to conduct the experiment. To minimize personnel exposure, it is highly advisable to conduct the experiment in an efficient fume hood. The fume hood should be free of clutter. The hood should not be used as a storage area for out of service equipment and supplies. Less clutter makes it easier to clean up a spill or extinguish a fire in the event of a release of an organolithium. The fume hood will also sweep fumes away more effectively with less clutter present. Combustible materials, such as solvents, flammable chemicals (reagents or samples), paper or cloth should be removed from the hood prior to the experiment. These are all potential fuel sources that can contribute to a fire in the event of spill of an organolithium. The fume hood must be equipped with a source of inert gas, such as nitrogen or argon. A delivery system to distribute the inert gas to the reactor, such as manifold or plastic lines, and a bubbler system are also required. The delivery system will be described in more detail in the next section. Equipment is also required to dry the glassware prior to the experiment.

Nitrogen or argon can be employed as the inert gas in reactions that employ organolithium reagents. Typically, nitrogen is available in several grades from the supplier. Select the grade with the lowest moisture and oxygen content. Argon must be utilized in reactions where lithium metal is a reactant. Nitrogen reacts exothermically with lithium metal to afford lithium nitride (Li_3N). Further, this reaction is catalyzed by moisture.

The glassware employed in the reaction must be free of moisture and oxygen before introducing the organolithium compound. There are several techniques routinely employed to dry and inert a reaction apparatus. One technique is to assemble the glassware in the hood, attach the inert gas line, evacuate the apparatus with a vacuum source, heat the apparatus with a heat gun for several minutes, isolate the vacuum, then refill the apparatus with the inert gas. This vacuum/inert gas cycle should be repeated several times. A popular alternative is to assemble the glassware in the hood, attach the inert gas line, start the flow of the gas, heat the apparatus with a heat gun for several minutes and then let it cool to room temperature in a stream of the inert gas. One additional technique for glassware drying/inerting is to place the individual glassware pieces in an oven to dry. The glassware should remain in the oven for at least several hours at 120°C, assembled hot in the hood, and allowed to cool to room temperature in a stream of inert gas. Alternatively, the glassware can be removed from the oven, placed in a desiccator to cool to room temperature, assembled in the hood then purged with the inert gas.

The proper personal protective equipment (PPE) for handling organolithium compounds should also be secured prior to experimentation. To protect the eyes from the corrosivity of organolithium compounds, eye protection in the form of safety glasses or goggles should always be worn. Additional eye protection, provided by a face shield, is recommended in experiments where higher volumes of organolithium reagents (greater than 1 L) are employed. The flammability and pyrophoricity hazards are mitigated by the use of a flame-resistant lab coat or coveralls.[12] Proper glove selection will provide protection for hands potentially exposed to the corrosive nature of the organolithium compounds and the organic solvents in which they are formulated. Gloves made of Viton® afford the best overall protection; however, they are expensive.[13] Nitrile gloves offer a good compromise between chemical protection and affordability.[14] Proper footwear, leather, closed-toe shoes, protect the feet from spills.

In the event of a spill, another important element to protection of personnel and equipment is a fire extinguisher. It is important to secure the appropriate fire extinguisher for organolithium reagents prior to initiation of the experiment. The recommended fire extinguisher is a Class B fire extinguisher.[15] It is imperative NOT to use fire extinguishers that contain water, carbon dioxide or halogenated hydrocarbons for organolithium fires. Alkyllithiums react violently with these three classes of extinguishing agents. The use of these improper extinguishers will exacerbate, rather than mitigate, the fire scenario.

LABORATORY SET-UP

A typical organolithium reaction apparatus, outfitted for cannula transfer, is illustrated schematically in Figure 3. The reactor is equipped with a mechanical stirrer, a pressure-equalizing addition funnel equipped with a septum, and a Claisen adapter fitted with a thermometer to measure internal temperature and a dry ice condenser. The inert gas line is attached to the outlet of the condenser, which is connected via a "T" fitting to a bubbler filled with mineral oil. This bubbler[16] monitors the positive flow of inert gas through the system and prevents the inflow of air into the reactor in the event of partial vacuum. A second inert gas line is employed for the reagent bottle of organolithium. The mineral oil bubbler on this side has a clamp on the outlet to facilitate transfer *via* the cannula. The reaction vessel and the organolithium should each be placed in a metal bowl. This serves as a catch pan for the organolithium solution in the event either breaks. In addition, the metal bowl surrounding the reaction vessel can be employed to hold the cooling medium for a cryogenic reaction. This cooling medium should be an inert hydrocarbon solvent, such as hexane or heptane, mixed with solid carbon dioxide, "dry ice." The more traditional cooling bath solvents, acetone or 2-propanol, react vigorously with organolithium solutions and should be avoided. Similarly, a water condenser should not be used, due to potential for leaks, which could enter the reaction vessel.

There are two basic techniques for the transfer of organolithium solutions in the laboratory, the syringe technique and the cannula technique.

TRANSFER TECHNIQUES

There are two basic techniques for the transfer of organolithium solutions in the laboratory, the syringe technique

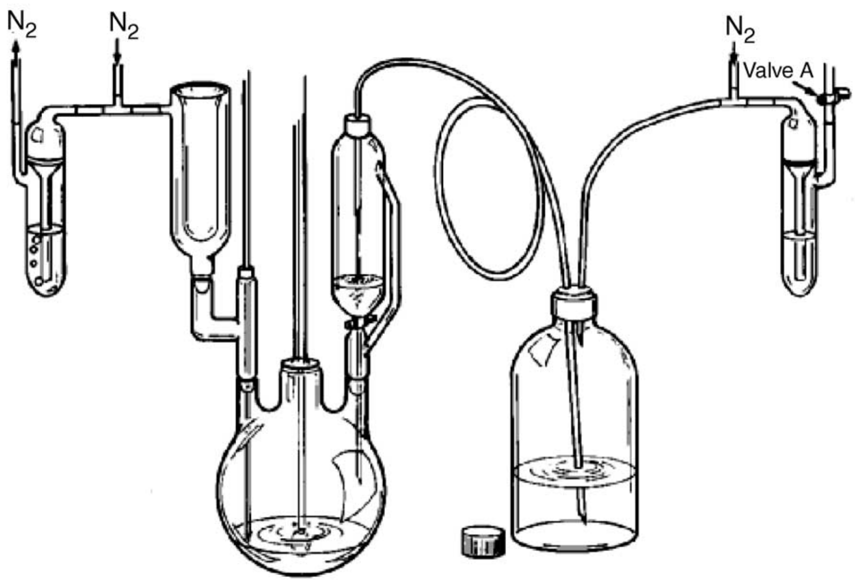


Figure 3. Laboratory apparatus for cannula transfer.

and the cannula technique. The two techniques are very similar. The syringe technique is preferred when relatively small volumes of organolithium solutions are required (less than 50 mL). The transfer of larger volumes is most easily accomplished with the cannula technique. The laboratory apparatus for a cannula transfer is illustrated in Figure 3.[17]

Syringe Technique

Clutter and combustibles are removed from the hood where the reaction will be conducted. The reaction apparatus is dried, purged with an inert gas and assembled in the hood using one of the techniques detailed previously. The reaction flask is placed in a metal bowl. The bottle of the organolithium compound is removed from the refrigerator and is clamped in the hood in a metal bowl. This minimizes the chance of a spill if the bottle is accidentally bumped during the transfer. It is recommended that the syringe be at least twice the volume of the organolithium to be dispensed. The syringe that will be employed in transfer must also be dried before it is employed. The syringe should be dried in an oven for at least 2 hr at 120°C, placed in a desiccator to cool to ambient temperature, then purged with a stream of inert gas. Don all the recommended PPE. If the reagent bottle for the organolithium compound was shipped with a solid cap from the supplier, it should be replaced with a cap with a septum. The inert gas flow is started on the reagent line. A standard syringe needle is inserted into the end of the inert gas line. The tip of this needle is then inserted into the septum of the reagent bottle. Observe the inert gas flow at the bubbler and adjust the flow accordingly. The syringe is then employed to withdraw the required amount of organolithium from the sample bottle. Care must be taken not to withdraw the organolithium solution faster than the inert gas flow can refill the void. This would allow air to enter the inert gas line and possibly contaminate the organolithium solution. The tip of the syringe needle is then inserted into the septum of the addition funnel. The organolithium solution is then dispensed into the funnel by pushing down on the syringe plunger. The solid cap is replaced on the sample bottle and it is returned to the refrigerator. The amount of the organolithium dispensed can be calculated by noting the final volume in the addition funnel. A more accurate technique for determining the amount of organolithium transferred is by weight. This is accomplished by weighing the sample bottle before and after the reagent has been dispensed. It is advisable to clean the syringe soon after the transfer is complete, to minimize the chance of the plunger sticking and "freezing" in the barrel. For pyrophoric solutions, any residue in the syringe should be diluted to less than 5 wt.% with an inert solvent, such as heptane. This rinse solution can then be quenched by slowly mixing with an equal volume of cold water.

Cannula Technique

Clutter and combustibles are removed from the hood where the reaction will be conducted. The reaction apparatus is dried, purged with an inert gas and assembled in the hood using one of the techniques detailed previously. The reaction flask is placed in a metal bowl. The bottle of the organolithium compound is removed from the refrigerator and is clamped in the hood in a metal bowl. This minimizes the chance of a spill if the bottle is accidentally bumped during the transfer. The cannula is a long syringe needle with a sharpened tip at each end. The cannula that will be employed in transfer must also be dried before it is employed. The cannula should be dried in an oven for at least 2 hr at 120°C, placed in a desiccator to cool to ambient temperature, then purged with a stream of inert gas. Don all the recommended PPE. If the reagent bottle for the organolithium compound was shipped with a solid cap from the supplier, it should be replaced with a cap with a septum. The inert gas flow is started on the reagent line. A standard syringe needle is inserted into the end of the inert gas line. The tip of this needle is then inserted into the septum of the sample bottle. Observe the inert gas flow at the bubbler and adjust the flow accordingly. One tip of the cannula is then inserted into the septum of the reagent bottle. The other tip of the cannula is inserted into the septum in the addition funnel. The tip of the cannula is lowered into the liquid of the organolithium solution. The clamp on the exit of the mineral oil bubbler attached to the reagent bottle is slowly closed. This causes pressure to build in the reagent bottle and the organolithium solution will transfer to the addition funnel. Inert gas pressure should never exceed 5 psi (0.3 bar). When the desired volume has been transferred, the clamp on the bubbler is released and the tip of the cannula is raised above the liquid level in the bottle. This latter action will prevent siphoning of the organolithium solution. Let any excess organolithium solution drain back into the reagent bottle by gravity. The cannula is removed from the reagent bottle and then from the addition funnel. The solid cap is replaced on the sample bottle and it is returned to the refrigerator. The amount of the organolithium dispensed can be calculated by noting the final volume in the addition funnel. A more accurate technique for determining the amount of organolithium transferred is by weight. This is accomplished by weighing the sample bottle before and after the reagent has been dispensed. It is advisable to clean the cannula soon after the transfer is complete, to minimize the chance of cannula plugging. For pyrophoric solutions, any residue in the cannula should be diluted to less than 5 wt.% with an inert solvent, such as heptane. This rinse solution can then be quenched by slowly mixing with an equal volume of cold water.

DISPOSAL OF ORGANOLITHIUM COMPOUNDS

Small residues of organolithium compounds can be safely quenched in a hood. Pyrophoric materials should be diluted to less than 5 wt.% with an inert solvent, such as heptane. This solution should then be added slowly (*via* an addition funnel) to well-stirred solution 2 M of 2-propanol in heptane. Monitor the temperature of this quench solution with an internal thermometer. Maintain the temperature at 50°C or below by controlling the feed rate of the organolithium solution or by application of an external cooling bath of dry ice/heptane. The resultant solution of lithium isopropoxide in heptane can then be disposed of as flammable, hazardous waste. Containers of organolithium reagents that have developed significant quantities of solids should be discarded. These larger volumes of organolithium reagents that are no longer needed should be sent out for disposal as a lab pack. This minimizes laboratory personnel exposure to the hazards of quenching large volumes of organolithium compounds and their decomposition products.

NEW DEVELOPMENTS

Several innovative organolithium compounds and formulations have recently been commercialized. These innovations have improved safety characteristics over the older, more traditional organolithium reagents. The first is 33 wt.% *n*-hexyllithium in hexanes. This 2.5 M solution of *n*-hexyllithium has similar reactivity to the analogous

> *Several innovative organolithium compounds and formulations have recently been commercialized. These innovations have improved safety characteristics over the older, more traditional organolithium reagents.*

concentration of *n*-butyllithium in typical applications. Furthermore, it exhibits two significant safety advantages over *n*-butyllithium. First, this formulation of *n*-hexyllithium in hexanes tested as non-pyrophoric, even at concentrations up to 85 wt.%.[7] The second advantage is that in deprotonation experiments, the co-product is *n*-hexane, a liquid with a boiling point of 67°C. A similar reaction with *n*-butyllithium would afford butane (boiling point = −0.5°C) as the co-product. *n*-Hexane is much easier to contain than butane, particularly on an industrial scale. Another innovation is the commercial availability of preformed solutions of lithium diisopropylamide (LDA). These formulations of LDA are non-pyrophoric.[7] In addition, when the preformed solution of LDA is employed, the experimenter does not have to handle pyrophoric *n*-butyllithium traditionally employed. A further advantage of the preformed LDA formulation is that again, the experimenter does not have to deal with the emission of the co-product butane. A third innovation is the newly commercialized formulation of *t*-butyllithium in heptane.[18] While this new formulation is still pyrophoric, it is much safer to handle than the traditional pentane formulation of *t*-butyllithium.[19] This is due to the much higher flash point of heptane (Fp = −1°C) versus pentane (Fp = −49°C).

CONCLUSIONS

Organolithium compounds are extremely useful reagents in organic synthesis and as initiators in anionic polymerizations. These reagents are corrosive, flammable and in certain cases, pyrophoric. However, these hazards can be minimized. The experiment should be carefully planned prior to its execution to minimize hazards to personnel and the physical plant. Proper PPE to mitigate the hazards of organolithium compounds should be secured and worn at all times. All equipment that is employed for the experiment must be free of moisture. An inert atmosphere of nitrogen or argon is also critical in minimizing the hazards of organolithium compounds. Solutions of organolithium compounds can be safely transferred from the storage bottles to the reaction flask with either a syringe or a cannula. With the utilization of these basic techniques, organolithium compounds can be safely handled in the laboratory. When properly handled, organolithiums provide unique properties that allow for precise control of a molecular architecture, while also demonstrating enhanced nucleophilicity, stability, and excellent solubility in organic solvents. With proper care and attention, organolithiums can be safely and effectively utilized in both laboratory and physical plant environments.

> *Organolithium compounds are extremely useful reagents in organic synthesis and as initiators in anionic polymerizations. These reagents are corrosive, flammable and in certain cases, pyrophoric. However, these hazards can be minimized.*

Acknowledgements

The authors would like to thank Doug Sutton for his practical suggestions on transfer techniques.

References

1. Wakefield, B. J. *The Chemistry of Organolithium Compounds*; Pergamon: Oxford, 1974;
   Wakefield, B. J. *Organolithium Methods*, Academic Press: London, 1988;
   Brandsma, L.; Verkruijsse, H. *Preparative Polar Organometallic Chemistry I*; Springer-Verlag: Berlin, 1987;
   Brandsma, L. *Preparative Polar Organometallic Chemistry II*; Springer-Verlag: Berlin, 1990;
   Stowell, J. C. *Carbanions in Organic Synthesis*; Wiley: New York, NY, 1979. (For the application of organolithium reagents in organic synthesis.)
2. Hsieh, H. L.; Quirk, R. P. *Anionic Polymerization*; Marcel Dekker: New York, NY, 1996. (For an excellent overview of anionic polymerization.)

3. Stanetty, P.; Mihovilovic, M. D. *J. Org. Chem.*, **1997**, *62*, 1514. (For example, the half-life of *n*-butyllithium in THF at 20°C is 1.78 hr. The half-lives of various alkyllithiums in ethereal solvents as a function of temperature.).
4. Malpass, D. B.; Fannin, L. W.; Ligi, J. J. *Kirk-Othmer Encyclopedia of Chemical Technology*, 3rd ed.; Grayson, M., Ed.; Wiley: New York, NY, 1981, Vol. 16, pp. 557–8.
5. March, J. *Advanced Organic Chemistry*, 5th ed.; Wiley: New York, NY, 2001, p. 330.
6. Pyrophoric is derived from the Greek word *pyrophoros*, which is a combination of *pyr* (fire) and *pherein* (to bear), in *Webster's New World Dictionary of American English*, 3rd College ed.; Prentice Hall: New York, NY, 1994, p. 1096.
7. The official test for pyrophoricity is detailed in the Department of Transportation (DOT) regulations (49 CFR 173, Appendix E).
8. Wakefield, B. J. *Organolithium Methods*; Academic Press: London, 1988, p. 12.
9. Totter, F.; Rittmeyer, P. *Organometallics in Synthesis: A Manual*; Schlosser, M., Ed.; Wiley: Chichester, 1994, pp. 171–2.
10. Kamienski, C. W.; McDonald, D. P.; Stark, M. W. *Kirk-Othmer Encyclopedia of Chemical Technology*, 4th ed.; Kroschwitz, J. I., Ed.; Wiley: New York, NY, 1995, Vol. 15, pp. 453–4.
11. Kamienski, C. W. *Lithium Link*, **1994** (Winter). (For an excellent review of the various methods of analysis of organolithium compounds.)
12. One brand of flame resistant fabric is Nomex®. A variety of clothing styles, including lab coats, coveralls, shirts and pants, is commercially available. Flame-resistant clothing is available from a number of laboratory supply vendors, including Aldrich, Fisher and VWR.
13. One pair of Viton® gloves, size 9, is listed in the 2000–2001 Aldrich catalog for $57.60.
14. One pair of nitrile gloves, size L, is listed in the 2000–2001 Aldrich catalog for $7.20.
15. Ansul® Purple K is one popular choice for a Class B fire extinguisher.
16. A number of bubbler designs are commercially available from laboratory glassware suppliers. A versatile bubbler design is Chemglass catalog number AF-0513-20.
17. *Butyllithium: Guidelines for Safe Handling*, a brochure available at no charge from FMC Lithium. (For a more extensive discussion of these transfer techniques.)
18. Commercially available from FMC Lithium, 449 N. Cox Road, Gastonia, NC 28054.
19. Bailey, B.; Longstaff, S. *Lithium Link*, **2000** (Fall). (For an excellent review of *t*-butyllithium chemistry.)

Appendix H: Risk Assessment Template and Examples

An electronic version of the risk assessment template (PDF and Word doc) is available at

http://www.mrl.ucsb.edu/~safinyaweb/lab.htm

This page intentionally left blank

LABORATORY RISK ASSESSMENT

This Laboratory Risk Assessment Form provides a framework for risk assessment. The goal is for researchers to systematically identify and control hazards to reduce risk of injuries and incidents. Review the section on Risk Assessment in the CHP for further information.

Conducting a risk assessment is required prior to working with a pyrophoric and/or water-reactive materials for the first time.

Remember the acronym **RAMP**: **R**ecognize the hazard; **A**ssess the risk; **M**inimize the risk; **P**repare for what can go wrong.

The risk assessment process involves rating the risk of the experiment from "low" to "unacceptable" risk. Consult with Prof. Safinya or Kai Ewert and EH&S if your risk rating is "high" or "unacceptable" to redesign the experiment and/or implement additional controls to reduce risk.

Procedure:	
PI / Lab Group: C. R. Safinya	
Department: Materials/Physics/MCDB	**Building / Location: MRL, Safinya labs**
Form Completed By:	**Start Date:**

1. RECOGNIZE THE HAZARD

Identify your research question and approach. What question are you trying to answer? What are you trying to measure or learn? What is your hypothesis? What approach or method will you use to answer your question? Are there alternative approaches?

Research Question(s)
Approach(s) or Method

Identify the general hazards (check all that apply). Perform background research to identify known risks of the reagents, reactions, or processes. Review protocols, Safety Data Sheets (SDSs), and safety information for hazardous chemicals, agents, or processes. Review accident histories within your laboratory/department.

Hazardous Agents

Physical Hazards of Chemicals

☐ Compressed gases

☐ Cryogens

☐ Explosives

☐ Flammables

☐ Organic peroxides

☐ Oxidizers

☐ Peroxide formers

☒ Pyrophorics

☐ Self-heating substances

☐ Self-reactive substances

☐ Substances which, in contact with water, emit flammable or toxic gases

Health Hazards of Chemicals

☐ Acute toxicity

☐ Carcinogens

☐ Eye damage/ irritation

☐ Germ cell mutagens

☐ Nanomaterials

☐ Reproductive toxins

☐ Respiratory or skin sensitization

☐ Simple asphyxiant

☐ Skin corrosion/ irritation

☐ Specific target organ toxicity

☐ Hazards not otherwise classified

Non-Ionizing Radiation

☐ Lasers, Class 3 or 4

☐ Lasers, Class 2

☐ Magnetic fields (e.g., NMR, MRI)

☐ RF/microwaves

☐ UV lamps

Ionizing Radiation

☐ Irradiator

☐ Radionuclide

☐ Radionuclide sealed source

☐ X-ray machine

☐ Other (list):

Hazardous Conditions or Processes

Reaction Hazards

☐ Explosive

☐ Exothermic, with potential for fire

☐ Endothermic, with potential for freezing solvents decreased solubility or heterogeneous mixtures

☐ Gases produced

☐ Hazardous reaction intermediates/products

☐ Hazardous side reactions

Hazardous Processes

☐ Generation of air contaminants (gases, aerosols, or particulates)

☐ Heating chemicals

☐ Large mass or volume

☐ Pressure > atmospheric

☐ Pressure < atmospheric

☐ Scale-up of reaction

Other Hazards

☐ Hand/power tools

☐ Moving equipment/parts

☐ Electrical

☐ Noise > 80 dBA

☐ Heat/hot surfaces

☐ Ergonomic hazards

☐ Needles/sharps

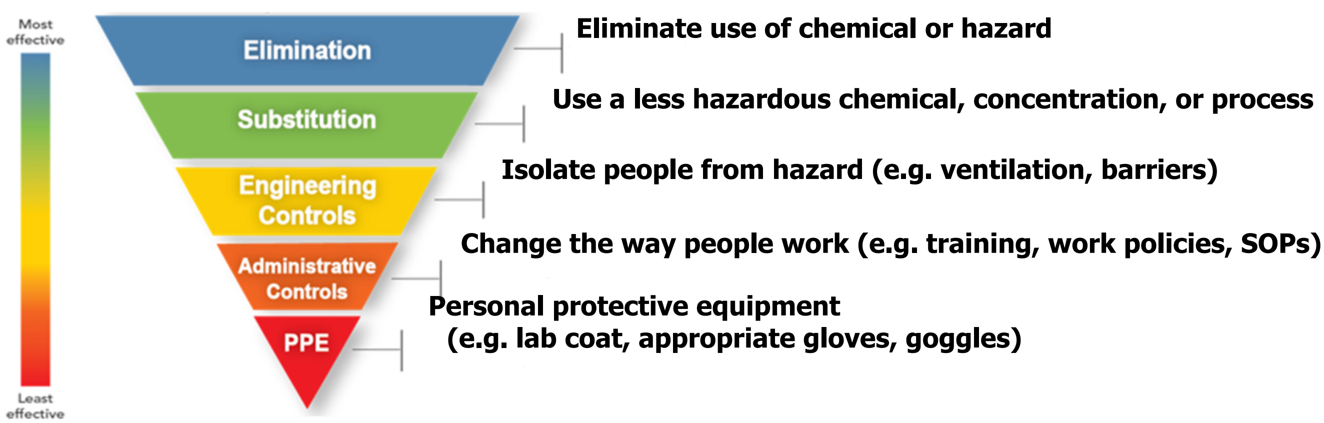
☐ Other (list):

2. ASSESS AND MINIMIZE THE RISK

Outline the Procedure. List the steps or tasks for your procedure and the hazard/potential consequences of each. Include set-up and clean-up steps or tasks. Define the hazard controls to minimize the risk of each step using the hierarchy of controls starting with the most effective (i.e., elimination, substitution, engineering controls, administrative controls, and personal protective equipment). List the hazard control measure you would use for each step or task (e.g., run at a micro scale, work in a fume hood, wear face shield and goggles).

Steps or Tasks	Hazard	Hazard Control Measure(s)

HIERARCHY OF CONTROLS



1 For guidance on selection of Personal Protective Equipment (PPE), see CHP and Lab Hazard Assessment Tool.
2 For guidance on selection of chemical-resistant gloves, see CHP or EH&S Website.

A hierarchy of controls should be applied starting with the most effective controls (i.e., elimination and substitution) at the top of the graphic and moving down. While personal protective equipment (PPE) should always be used, it should be considered the last line of defense from potential hazards.

Select the appropriate PPE and safety supplies for the procedure (check all that apply).

Laboratory PPE/Safety Supplies

☒ Appropriate street clothing (long pants, closed shoes)

☒ Gloves; indicate type: ___________

☒ Safety glasses

☐ Safety goggles

☐ Face shield and googles

☐ Lab coat

☒ Flame-resistant lab coat

☒ Fire extinguisher

☒ Eyewash/safety shower

☒ First aid kit

☒ Spill kit

☐ Specialized medical supplies (e.g. calcium gluconate for hydrofluoric acid and amyl nitrite for cyanides

☐ Other (list):

Identify the appropriate training (check all that apply). Identify the general safety and procedure based/specific training appropriate for your procedure.

General Safety Training

General/Chemical Safety

☒ Lab Safety Compliance & Practices

☒ Managing Lab Chemicals

☐ Compressed Gas Safety

☒ Fume Hood Training

Job Specific Training

☒ Lab/job-specific training

☒ Lab SOP(s) to review (list):

Pyrophoric and/or Water-Reactive Materials

☐ Equipment SOP(s) to review (list):

☐ Other (list):

Assign a risk rating to the experiment. Based on your procedure outline and the what if analysis, determine the risk rating for the experiment or procedure.

Risk Rating: _____________

The Risk Rating is subjective. The primary goal is for researchers to think about risk, and differentiate unacceptable and high-level risk steps from those with a lower level risk. This will help drive additional consultation and control measures where needed.

Likelihood of Incident Occurrence	Severity of Consequences – Personnel Safety: No injuries	Minor Injury	Significant Injury	Life threatening
Very Likely	Low	High *	Unacceptable **	Unacceptable **
Likely	Low	Medium	High *	Unacceptable **
Possible	Low	Medium	High *	High *
Rare	Low	Low	Medium	High *

Revise plan if the risk rating is too high. Are these risks acceptable? Use this table to determine the action to take based on the risk rating. What are the highest risk steps? What more can you do to control the risks? Return to planning and use the hierarchy of controls to design a safer experiment.

Hazard Risk Level	Action
Unacceptable **	**STOP!** Additional controls needed to reduce risk. **Consult with PI.**
High *	Additional controls recommended to reduce risk. **Consult with PI.**
Medium	Ensure you are following best practices. Consult with peers, PI, and EH&S as needed.
Low	Perform work within controls

NOTE: **Unacceptable risk-rated experiments **should not proceed**. Introduce further controls to reduce risk. Contact Prof. Safinya, Kai Ewert, or EH&S for recommendations and best practices.

3. PREPARE FOR WHAT CAN GO WRONG

Question your methods. What have you missed and who can advise you? Challenge your hazard control measures by asking "What if…?" questions. "What if" questions should challenge you to find the gaps in your knowledge or logic. Include possible accident scenarios. Factors to consider are human error, equipment failures, and deviations from the planned/expected parameters (e.g., temperature, pressure, time, flow rate, and scale/concentration). Update your plan to include any new controls required to address these possibilities.

What If Analysis
What if…? Examples: there is a loss of cooling? …valves/stopcocks are left open/closed? …there is unexpected over-pressurization? …a spill occurs?
Then… there may be a runaway reaction. …there may be an unexpected splash potential. …the reaction vessel may fail. …there may be a dermal exposure. …there may be an eye injury.
What if…?
Then…
What if…?
Then…
What if…?
Then…
What if…?
Then…
What if…?
Then…

Procedure Risk Assessment is Complete	
Form Completed By: Kai Ewert	
Signature:	**Date:3/30/2023**
PI / Supervisor Signature:	

OPTIONAL STEPS

Perform a trial run. How you can test your experimental design? Can you do a dry run of the procedure without hazardous chemicals/reagents/gases to familiarize yourself with equipment and demonstrate your ability to manipulate the experimental apparatus? Can you run the procedure with a less hazardous material? Can you test your experimental design at a smaller scale? If your procedure requires multiple people, would a table top exercise be useful?

Trial Run
Trial Run Procedure / Date:
Did the trial go as expected? Yes ☐ No ☐
Experimental design changes needed (if any):

Perform and evaluate. Run your procedure using the appropriate controls you've identified. Evaluate controls and hazards as you work. Critique the controls and process you used by answering the following questions. If changes to controls are needed, update your risk assessment tool and re-evaluate any time you revise your process (e.g. changes in scale, reagent, equipment, or conditions that might increase the hazard/risk). Share your assessment with your PI/colleagues for the next iteration of the experiment.

Evaluate Your Procedure
What went well?
Did the controls perform as expected?
Did anything unexpected occur?
Did a hazard manifest itself that was not previously identified?
Were there any close calls or near misses that indicate areas of needed improvement?
Did something go exceptionally well that others could learn from?
I plan to evolve my procedure by...

LABORATORY RISK ASSESSMENT

This Laboratory Risk Assessment Form provides a framework for risk assessment. The goal is for researchers to systematically identify and control hazards to reduce risk of injuries and incidents. Review the section on Risk Assessment in the CHP for further information.

Conducting a risk assessment is required prior to working with a pyrophoric and/or water-reactive materials for the first time.

Remember the acronym **RAMP**: **R**ecognize the hazard; **A**ssess the risk; **M**inimize the risk; **P**repare for what can go wrong.

The risk assessment process involves rating the risk of the experiment from "low" to "unacceptable" risk. Consult with Prof. Safinya or Kai Ewert and EH&S if your risk rating is "high" or "unacceptable" to redesign the experiment and/or implement additional controls to reduce risk.

Procedure: Use of catalytic amounts of *n*-butyl lithium (*n*BuLi) in the esterification of carboxylic acids with alcohols mediated by carbonyl diimidazole (CDI)	
PI / Lab Group: C. R. Safinya	
Department: Materials/Physics/MCDB	**Building / Location: MRL, Safinya labs**
Form Completed By: Kai Ewert	**Start Date: 3/31/2023**

1. RECOGNIZE THE HAZARD

Identify your research question and approach. What question are you trying to answer? What are you trying to measure or learn? What is your hypothesis? What approach or method will you use to answer your question? Are there alternative approaches?

Research Question(s)
Prepare e.g. 1,2-diacyl-3-dimethylaminopropanes from the corresponding carboxylic acids and 1,2-dihydroxy-3-dimethylaminopropane.
Approach(s) or Method
Ester formation mediated by CDI with catalytic *n*BuLi (hexane solution)

Identify the general hazards (check all that apply). Perform background research to identify known risks of the reagents, reactions, or processes. Review protocols, Safety Data Sheets (SDSs), and safety information for hazardous chemicals, agents, or processes. Review accident histories within your laboratory/department.

Hazardous Agents

Physical Hazards of Chemicals

☐ Compressed gases
☐ Cryogens
☐ Explosives
☒ Flammables
☐ Organic peroxides
☐ Oxidizers
☐ Peroxide formers
☒ Pyrophorics
☐ Self-heating substances
☐ Self-reactive substances
☒ Substances which, in contact with water, emit flammable or toxic gases

Health Hazards of Chemicals

☐ Acute toxicity
☐ Carcinogens
☒ Eye damage/ irritation
☐ Germ cell mutagens
☐ Nanomaterials
☐ Reproductive toxins
☐ Respiratory or skin sensitization
☐ Simple asphyxiant
☒ Skin corrosion/ irritation
☒ Specific target organ toxicity (CNS)
☐ Hazards not otherwise classified

Ionizing Radiation

☐ Irradiator
☐ Radionuclide
☐ Radionuclide sealed source
☐ X-ray machine

Non-Ionizing Radiation

☐ Lasers, Class 3 or 4
☐ Lasers, Class 2
☐ Magnetic fields (e.g., NMR, MRI)
☐ RF/microwaves
☐ UV lamps

Biohazards

☐ BSL-2 Biological agents
☐ BSL-3 Biological agents
☐ Human cells/blood/ BBP
☐ NHPs/cells/blood
☐ Non-exempt rDNA
☐ Animal work
☐ High risk animals (RC1)
☐ Other (list):

Hazardous Conditions or Processes

Reaction Hazards

☐ Explosive
☒ Exothermic, with potential for fire
☐ Endothermic, with potential for freezing solvents decreased solubility or heterogeneous mixtures
☒ Gases produced
☐ Hazardous reaction intermediates/products
☐ Hazardous side reactions

Hazardous Processes

☐ Generation of air contaminants (gases, aerosols, or particulates)
☐ Heating chemicals
☐ Large mass or volume
☐ Pressure > atmospheric
☐ Pressure < atmospheric
☐ Scale-up of reaction

Other Hazards

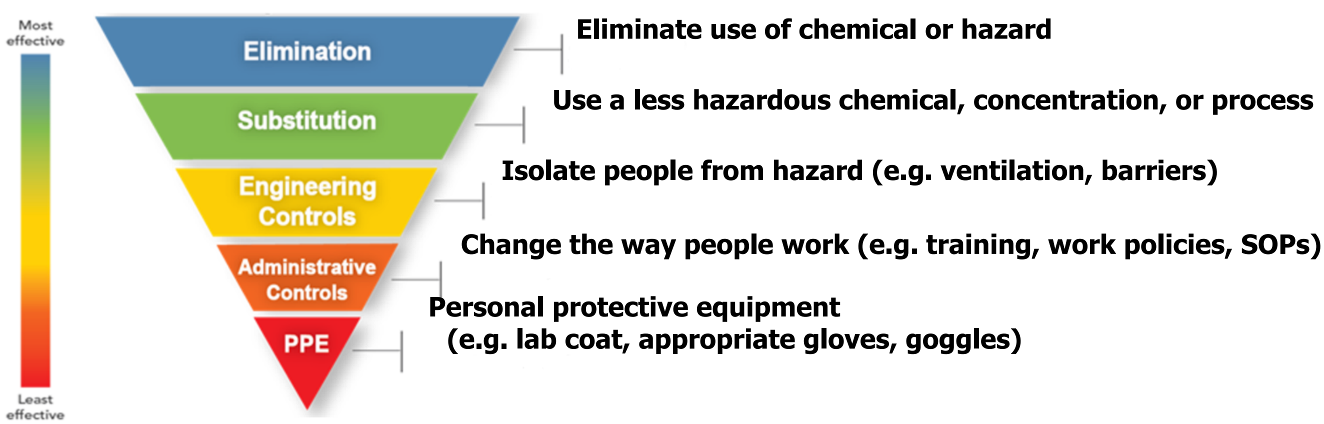
☐ Hand/power tools
☐ Moving equipment/parts
☐ Electrical
☐ Noise > 80 dBA
☐ Heat/hot surfaces
☐ Ergonomic hazards
☐ Needles/sharps
☐ Other (list):

2. ASSESS AND MINIMIZE THE RISK

Outline the Procedure. List the steps or tasks for your procedure and the hazard/potential consequences of each. Include set-up and clean-up steps or tasks. Define the hazard controls to minimize the risk of each step using the hierarchy of controls starting with the most effective (i.e., elimination, substitution, engineering controls, administrative controls, and personal protective equipment). List the hazard control measure you would use for each step or task (e.g., run at a micro scale, work in a fume hood, wear face shield and goggles).

Steps or Tasks	Hazard	Hazard Control Measure(s)
measure out *n*BuLi solution	reaction with air/moisture	Using standard inert gas techniques to exclude air/moisture, a syringe is used to withdraw the solution from the main container
Add *n*BuLi to the reaction mixture	exothermic reaction; hydrogen gas evolution;	air/moisture is excluded from the reaction setup; the *n*BuLi solution is added to the reaction mixture immediately after drawing it into the syringe;

HIERARCHY OF CONTROLS



1 For guidance on selection of Personal Protective Equipment (PPE), see CHP and Lab Hazard Assessment Tool.
2 For guidance on selection of chemical-resistant gloves, see CHP or EH&S Website.

A hierarchy of controls should be applied starting with the most effective controls (i.e., elimination and substitution) at the top of the graphic and moving down. While personal protective equipment (PPE) should always be used, it should be considered the last line of defense from potential hazards.

Select the appropriate PPE and safety supplies for the procedure (check all that apply).

Laboratory PPE/Safety Supplies	
☒ Appropriate street clothing (long pants, closed shoes)	☒ First aid kit
☒ Gloves; indicate type: __neoprene with Kevlar liner_	☒ Spill kit
☒ Safety glasses	☐ Specialized medical supplies (e.g. calcium gluconate for hydrofluoric acid and amyl nitrite for cyanides
☐ Safety goggles	☐ Other (list):
☐ Face shield and googles	
☐ Lab coat	
☒ Flame-resistant lab coat	
☒ Fire extinguisher	
☒ Eyewash/safety shower	

Identify the appropriate training (check all that apply). Identify the general safety and procedure based/specific training appropriate for your procedure.

General Safety Training

General/Chemical Safety

☒ Lab Safety Compliance & Practices

☒ Managing Lab Chemicals

☐ Compressed Gas Safety

☒ Fume Hood Training

Job Specific Training

☒ Lab/job-specific training

☒ Lab SOP(s) to review (list):

Pyrophoric and/or Water-Reactive Materials

☐ Equipment SOP(s) to review (list):

☐ Other (list):

Assign a risk rating to the experiment. Based on your procedure outline and the what if analysis, determine the risk rating for the experiment or procedure.

Risk Rating: __Low_____

The Risk Rating is subjective. The primary goal is for researchers to think about risk, and differentiate unacceptable and high-level risk steps from those with a lower level risk. This will help drive additional consultation and control measures where needed.

Likelihood of Incident Occurrence	Severity of Consequences – Personnel Safety: No injuries	Minor Injury	Significant Injury	Life threatening
Very Likely	Low	High *	Unacceptable **	Unacceptable **
Likely	Low	Medium	High *	Unacceptable **
Possible	Low	Medium	High *	High *
Rare	Low	Low	Medium	High *

Revise plan if the risk rating is too high. Are these risks acceptable? Use this table to determine the action to take based on the risk rating. What are the highest risk steps? What more can you do to control the risks? Return to planning and use the hierarchy of controls to design a safer experiment.

Hazard Risk Level	Action
Unacceptable **	**STOP!** Additional controls needed to reduce risk. **Consult with PI.**
High *	Additional controls recommended to reduce risk. **Consult with PI.**
Medium	Ensure you are following best practices. Consult with peers, PI, and EH&S as needed.
Low	Perform work within controls

NOTE: ****Unacceptable** risk-rated experiments **should not proceed**. Introduce further controls to reduce risk. Contact Prof. Safinya, Kai Ewert, or EH&S for recommendations and best practices.

3. PREPARE FOR WHAT CAN GO WRONG

Question your methods. What have you missed and who can advise you? Challenge your hazard control measures by asking "What if…?" questions. "What if" questions should challenge you to find the gaps in your knowledge or logic. Include possible accident scenarios. Factors to consider are human error, equipment failures, and deviations from the planned/expected parameters (e.g., temperature, pressure, time, flow rate, and scale/concentration). Update your plan to include any new controls required to address these possibilities.

What If Analysis
What if…? Examples: there is a loss of cooling? …valves/stopcocks are left open/closed? …there is unexpected over-pressurization? …a spill occurs?
Then… there may be a runaway reaction. …there may be an unexpected splash potential. …the reaction vessel may fail. …there may be a dermal exposure. …there may be an eye injury.
What if…? *n*BuLi solution spills from the syringe or bottle when measuring it out
Then… the nBuLi solution may react with air or moisture, possibly igniting. This may be mitigated by working in a hood that has been cleared of all unnecessary items and having a container with sand or lime (CaO) on hand to quench the syringe tip or small fires of spilled drops.
What if…? the nBuLi solution is added too quickly to the reaction mixture
Then… gas (butane) will evolve rapidly, resulting in a pressure increase or splattering. This may be mitigated by working in a system that is closed except for an appropriate method of venting (pressure release needle or oil bubbler).
What if…?
Then…

Procedure Risk Assessment is Complete	
Form Completed By: Kai Ewert	
Signature:	**Date:4/3/2023**
PI / Supervisor Signature:	

This page intentionally left blank

LABORATORY RISK ASSESSMENT

This Laboratory Risk Assessment Form provides a framework for risk assessment. The goal is for researchers to systematically identify and control hazards to reduce risk of injuries and incidents. Review the section on Risk Assessment in the CHP for further information.

Conducting a risk assessment is required prior to working with a pyrophoric and/or water-reactive materials for the first time.

Remember the acronym **RAMP**: **R**ecognize the hazard; **A**ssess the risk; **M**inimize the risk; **P**repare for what can go wrong.

The risk assessment process involves rating the risk of the experiment from "low" to "unacceptable" risk. Consult with Prof. Safinya or Kai Ewert and EH&S if your risk rating is "high" or "unacceptable" to redesign the experiment and/or implement additional controls to reduce risk.

Procedure: Use of lithium aluminum hydride for reduction of carboxylic acids to the corresponding alcohols	
PI / Lab Group: C. R. Safinya	
Department: Materials/Physics/MCDB	**Building / Location: MRL, Safinya labs**
Form Completed By: Kai Ewert	**Start Date: 3/31/2023**

1. RECOGNIZE THE HAZARD

Identify your research question and approach. What question are you trying to answer? What are you trying to measure or learn? What is your hypothesis? What approach or method will you use to answer your question? Are there alternative approaches?

Research Question(s)
Prepare e.g. oleyl alcohol from oleic acid.
Approach(s) or Method
Reduction of oleic acid using lithium aluminum hydride (LAH)

Identify the general hazards (check all that apply). Perform background research to identify known risks of the reagents, reactions, or processes. Review protocols, Safety Data Sheets (SDSs), and safety information for hazardous chemicals, agents, or processes. Review accident histories within your laboratory/department.

Hazardous Agents

Physical Hazards of Chemicals

☐ Compressed gases

☐ Cryogens

☐ Explosives

☒ Flammables

☐ Organic peroxides

☐ Oxidizers

☒ Peroxide formers

☒ Pyrophorics

☐ Self-heating substances

☐ Self-reactive substances

☒ Substances which, in contact with water, emit flammable or toxic gases

Health Hazards of Chemicals

☐ Acute toxicity

☐ Carcinogens

☒ Eye damage/ irritation

☐ Germ cell mutagens

☐ Nanomaterials

☐ Reproductive toxins

☐ Respiratory or skin sensitization

☐ Simple asphyxiant

☒ Skin corrosion/ irritation

☐ Specific target organ toxicity

☐ Hazards not otherwise classified

Ionizing Radiation

☐ Irradiator

☐ Radionuclide

☐ Radionuclide sealed source

☐ X-ray machine

Non-Ionizing Radiation

☐ Lasers, Class 3 or 4

☐ Lasers, Class 2

☐ Magnetic fields (e.g., NMR, MRI)

☐ RF/microwaves

☐ UV lamps

Biohazards

☐ BSL-2 Biological agents

☐ BSL-3 Biological agents

☐ Human cells/blood/ BBP

☐ NHPs/cells/blood

☐ Non-exempt rDNA

☐ Animal work

☐ High risk animals (RC1)

☐ Other (list):

Hazardous Conditions or Processes

Reaction Hazards

☐ Explosive

☒ Exothermic, with potential for fire, excessive heat, or runaway reaction

☐ Endothermic, with potential for freezing solvents decreased solubility or heterogeneous mixtures

☒ Gases produced

☒ Hazardous reaction intermediates/products

☐ Hazardous side reactions

Hazardous Processes

☐ Generation of air contaminants (gases, aerosols, or particulates)

☐ Heating chemicals

☐ Large mass or volume

☐ Pressure > atmospheric

☐ Pressure < atmospheric

☐ Scale-up of reaction

Other Hazards

☐ Hand/power tools

☐ Moving equipment/parts

☐ Electrical

☐ Noise > 80 dBA

☐ Heat/hot surfaces

☐ Ergonomic hazards

☐ Needles/sharps

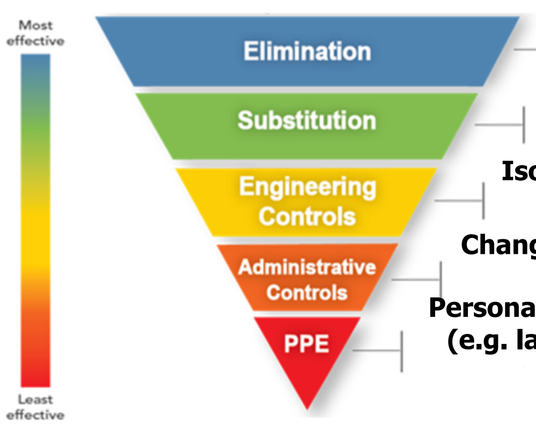
☐ Other (list):

2. ASSESS AND MINIMIZE THE RISK

Outline the Procedure. List the steps or tasks for your procedure and the hazard/potential consequences of each. Include set-up and clean-up steps or tasks. Define the hazard controls to minimize the risk of each step using the hierarchy of controls starting with the most effective (i.e., elimination, substitution, engineering controls, administrative controls, and personal protective equipment). List the hazard control measure you would use for each step or task (e.g., run at a micro scale, work in a fume hood, wear face shield and goggles).

Steps or Tasks	Hazard	Hazard Control Measure(s)
Weight and suspend LAH in ether	reaction with air/moisture	weighing is performed as swiftly as feasible, keeping containers capped as much as possible dry ether is used and air/moisture is excluded from the setup
React oleic acid with LAH	exothermic/runaway reaction; hydrogen gas evolution;	air/moisture is excluded from the reaction setup; control of addition speed of oleic acid solution; reflux cooler and optional water bath for cooling the flask
Quench reaction/LAH	exothermic/runaway reaction; hydrogen gas evolution;	slow and controlled addition of quenching reagents (wet ether/water); reflux cooler and water bath for cooling the flask

HIERARCHY OF CONTROLS



Eliminate use of chemical or hazard

Use a less hazardous chemical, concentration, or process

Isolate people from hazard (e.g. ventilation, barriers)

Change the way people work (e.g. training, work policies, SOPs)

Personal protective equipment (e.g. lab coat, appropriate gloves, goggles)

1 For guidance on selection of Personal Protective Equipment (PPE), see CHP and Lab Hazard Assessment Tool.
2 For guidance on selection of chemical-resistant gloves, see CHP or EH&S Website.

A hierarchy of controls should be applied starting with the most effective controls (i.e., elimination and substitution) at the top of the graphic and moving down. While personal protective equipment (PPE) should always be used, it should be considered the last line of defense from potential hazards.

Select the appropriate PPE and safety supplies for the procedure (check all that apply).

Laboratory PPE/Safety Supplies

☒ Appropriate street clothing (long pants, closed shoes)

☒ Gloves; indicate type: ___nitrile or neoprene with Kevlar liner______________________

☒ Safety glasses

☐ Safety goggles

☐ Face shield and googles

☐ Lab coat

☒ Flame-resistant lab coat

☒ Fire extinguisher

☒ Eyewash/safety shower

☒ First aid kit

☒ Spill kit

☐ Specialized medical supplies (e.g. calcium gluconate for hydrofluoric acid and amyl nitrite for cyanides

☐ Other (list):

Identify the appropriate training (check all that apply). Identify the general safety and procedure based/specific training appropriate for your procedure.

General Safety Training

General/Chemical Safety

☒ Lab Safety Compliance & Practices

☒ Managing Lab Chemicals

☐ Compressed Gas Safety

☒ Fume Hood Training

Job Specific Training

☒ Lab/job-specific training

☒ Lab SOP(s) to review (list):

Pyrophoric and/or Water-Reactive Materials

☐ Equipment SOP(s) to review (list):

☐ Other (list):

Assign a risk rating to the experiment. Based on your procedure outline and the what if analysis, determine the risk rating for the experiment or procedure.

Risk Rating: __Medium_____

The Risk Rating is subjective. The primary goal is for researchers to think about risk, and differentiate unacceptable and high-level risk steps from those with a lower level risk. This will help drive additional consultation and control measures where needed.

Likelihood of Incident Occurrence	Severity of Consequences – Personnel Safety			
	No injuries	Minor Injury	Significant Injury	Life threatening
Very Likely	Low	High *	Unacceptable **	Unacceptable **
Likely	Low	Medium	High *	Unacceptable **
Possible	Low	Medium	High *	High *
Rare	Low	Low	Medium	High *

Revise plan if the risk rating is too high. Are these risks acceptable? Use this table to determine the action to take based on the risk rating. What are the highest risk steps? What more can you do to control the risks? Return to planning and use the hierarchy of controls to design a safer experiment.

Hazard Risk Level	Action
Unacceptable **	**STOP!** Additional controls needed to reduce risk. **Consult with PI.**
High *	Additional controls recommended to reduce risk. **Consult with PI.**
Medium	Ensure you are following best practices. Consult with peers, PI, and EH&S as needed.
Low	Perform work within controls

NOTE: **Unacceptable risk-rated experiments **should not proceed**. Introduce further controls to reduce risk. Contact Prof. Safinya, Kai Ewert, or EH&S for recommendations and best practices.

3. PREPARE FOR WHAT CAN GO WRONG

Question your methods. What have you missed and who can advise you? Challenge your hazard control measures by asking "What if…?" questions. "What if" questions should challenge you to find the gaps in your knowledge or logic. Include possible accident scenarios. Factors to consider are human error, equipment failures, and deviations from the planned/expected parameters (e.g., temperature, pressure, time, flow rate, and scale/concentration). Update your plan to include any new controls required to address these possibilities.

What If Analysis
What if…? There is a loss of cooling?
Then… the reaction may overheat. This may be mitigated by stopping addition of oleic acid or reinstating water flow to the reflux cooler.
What if…? Quenching solutions are added too quickly
Then… the reaction may "boil over", spilling out of the cooler/apparatus and releasing flammable gas and liquid
What if…? The apparatus is completely closed by mistake, e.g. by omitting the drying tube and using a stopper instead
Then… excess ressure may develop in the apparatus from hydrogen evolution, resulting in breakage or separation of the setup at glass joints.

Procedure Risk Assessment is Complete	
Form Completed By: Kai Ewert	
Signature:	**Date: 4/3/2023**
PI / Supervisor Signature:	

This page intentionally left blank

Appendix I:
A Cautionary Tale From the Past

Article by K. Barry Sharpless (two-time Nobel prize winner) on How He Lost an Eye Due to Not Wearing Safety Glasses

Retrieved on 2022-07-21 from https://news.mit.edu/1992/safety-0311

Many of you may know that I was blinded in one eye during a lab accident in 1970, shortly after I arrived at MIT as an assistant professor. I always wore glasses whenever I was at my bench, and while I felt I conscientiously observed safety measures, my experience proves one can't be too cautious about wearing safety glasses.

As I prepared to go home from the lab during the early hours of the morning of the accident, I looked in the bays to see what my co-workers were doing, and then returned to my own bench, removed my safety glasses, and put on my parka. As I was walking to the door, I passed the bench where a first-year graduate student was flame-sealing an NMR tube. I asked how it was going, and he replied, "Good, I've got it sealed."

He was sealing off the tube at atmospheric pressure under a flow of nitrogen gas while cooling the tube in a liquid nitrogen bath, a technique neither of us had performed before. Nor, I regret to say, had we looked up the procedure, which we subsequently discovered to be incorrect.

I stopped by his bench, picked up the tube from the bath, and held it to the light. The tube immediately frosted over, and, as I wiped it to better see the contents, I noticed that the solvent level was exceedingly high. Suddenly the solvent level dropped several inches. Though I instantly realized condensed oxygen had been sealed in the NMR tube, I was quite literally unable to move a muscle before it exploded. Glass fragments shredded my cornea, penetrated the iris, and cause the partial collapse of one eye. My only other injuries were superficial face cuts.

My first two weeks at Mass Eye & Ear were spent totally immobilized and with *both* eyes bandaged. The pain was terrific, but my fear was even greater: I had been warned that when my eyes were uncovered there was a small chance I might blind in *both* eyes due to "sympathetic ophthalmia." Because eyes are walled off from the rest of the body *in utero*, eye protein driven into the blood stream can raise an immune response that leads to the "killing" of the uninjured eye. My disappointment at having no functional vision in my injured eye was, needless to say, surpassed by my joy at retaining full vision in my good eye.

The lesson to be learned from my experience is straightforward: there's simply never an adequate excuse for not wearing safety glasses in the laboratory *at all times*.

K. Barry Sharpless, | Professor
Publication Date: March 11, 1992
A version of this article appeared in the March 11, 1992 issue of MIT Tech Talk (Volume 36, Number 23).

This page intentionally left blank

UCSB Laboratory Safety Manual and Chemical Hygiene Plan

Prepared by UCSB Environmental Health & Safety

SECTION II (2):

UCSB POLICIES, PROCEDURES AND RESOURCES

This section of the document is now provided to laboratories in an electronic version only – see URL (Web address) provided below.

Web address (URL) for Section II: http://www.ehs.ucsb.edu/labsafety-chp/

Per Cal-OSHA requirements, this document needs to be reviewed and updated ***annually****. Therefore, please refer to the web version for the most recent update. The PDF and hardcopy versions of this CHP contain the version of Section II that is current as of the date of the last revision of this CHP. This version of Section II is only provided for your convenience, without implying that it is the current version.*

Questions can be directed to Alex Moretto at amoretto@ucsb.edu

See also the Table of Contents – UCSB Chemical Hygiene Plan webpage at

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp

This page intentionally left blank

CHEMICAL HYGIENE PLAN

and Laboratory Safety Manual

A Written Safety Program for Laboratories Utilizing Hazardous Chemicals

Publication Date January 2023

Contents

Publication date January 2023

Chapter 1: Introduction

Scope of this document

UC Santa Barbara is committed to providing a healthy and safe working environment for the campus community. In the case of laboratory personnel, a formal safety program is outlined in the form of the Chemical Hygiene Plan, as required by Cal/OSHA regulation 8 CCR §5191, also known as the *'Laboratory Standard'*. This document describes the training and controls in place to protect laboratory personnel against adverse health and safety hazards associated with exposure to potentially hazardous chemicals. This includes all proper use and handling practices and procedures to be followed by faculty, staff, students, visiting scholars, volunteers, and all other personnel working with potentially hazardous chemicals in a laboratory setting.

To be defined as a laboratory setting, the following criteria must be met:

- Chemical manipulations are on a scale that is easily and safely manipulated by one person (lab scale).
- Multiple chemical procedures are used.
- Procedures are not part of a production process, nor simulate a production process.
- Protective laboratory practices and equipment are available and commonly used.

The information presented in this document represents best practices and provides a broad overview of the information necessary for the safe operation of laboratories that utilize potentially hazardous chemicals. It is not intended to be all inclusive, nor should it be considered a complete Chemical Hygiene Plan. To be considered a complete Chemical Hygiene Plan, this document must be accompanied by a set of Standard Operating Procedures developed by researchers and approved by the Principal Investigator/Laboratory supervisor. Templates for the development of these SOP's are available from Environmental Health and Safety.

The CHP does not apply to research involving *exclusively* radiological or biological materials, as these safety procedures and regulatory requirements are outlined separately in the Radiation Safety Manual and the Biosafety Guide respectively. Research that involves more than one type of hazard must comply with all applicable regulatory requirements and follow guidance outlined in the relevant safety manuals.

Areas that are defined as laboratories by the university, but that use no chemicals or only a limited amount of specific low-hazard chemicals, may be exempt from the requirement to have a Chemical Hygiene Plan. Upon receiving this exemption, these laboratories will be required instead to comply with the Injury and Illness Protection Program or the Hazard Communication Standard, respectively. Any PI/Laboratory Supervisor wishing to investigate this possibility should contact EH&S for a hazard assessment.

Rights and Responsibilities

Rights	Responsibilities
☐ **Safe work environment**	☐ **Comply with applicable safety laws, regulations and UC polices.**
☐ **Safety training**	☐ **Attend any required safety training**
☐ **Report safety concerns without fear of reprisal**	☐ **Correct or report uncontrolled hazards**
☐ **Exposure to chemicals, noise and heat only at safe levels**	☐ **Obtain and use safety Information (SDS)**

<u>Responsibilities of All Personnel who handle Potentially Hazardous Chemicals</u>

All personnel in research or teaching laboratories that use or store potentially hazardous chemicals are responsible for:

1. Completing all required trainings and refreshers. Ensuring that this training has been documented on a Training Needs Assessment form.

2. Reviewing, understanding and following the Chemical Hygiene Plan and all other appropriate Safety Manuals and Policies as determined by the hazards present in the laboratory.

3. Following all verbal and written rules, Standard Operating Procedures and policies established by the PI/Laboratory Supervisor.

4. Developing good personal chemical hygiene habits, including keeping the work area safe and uncluttered, ensuring that fume hoods are not used for storage, etc.

5. Immediately reporting unsafe acts, unsafe conditions and lab accidents to the PI/Laboratory Supervisor, and being prepared for laboratory accidents and emergencies (knowing emergency response procedures).

6. Assessing and controlling hazards associated with their experiments and work area prior to conducting work, including consistent and proper use of Engineering Controls (e.g. fume hoods),

Administrative Controls (e.g. SOP's), and Personal Protective Equipment (e.g. safety glasses and lab coats).

7. Following all UC Santa Barbara, state and federal requirements for the collection and disposal of hazardous waste.

8. When working autonomously or performing independent research work:
    a. Reviewing the plan or scope of work for their proposed research with the PI/Laboratory Supervisor.
    b. Notifying in writing and consulting with the PI/Laboratory Supervisor, in advance, if they intend to significantly deviate from previously reviewed procedures. Examples of significant changes include change in objectives, change in experimental conditions, change in required PPE, and reduction or elimination of administrative and/or engineering controls.
    c. Preparing SOPs and hazard analyses and performing literature searches relevant to safety and health that are appropriate for their work, and
    d. Providing appropriate oversight, training and safety information to personnel they supervise.

9. Disposing of, or transferring to new ownership, all research materials in advance of leaving their assigned laboratory space (e.g. leaving the research group, leaving UCSB, relocating to new space).

Responsibilities of the Principal Investigator/Laboratory Supervisor

The Principle Investigator or person responsible for the laboratory space has the responsibility for the health and safety of all personnel working in his or her laboratory who handle hazardous chemicals. *The tasks and duties related to this may be delegated, but the responsibility for ensuring that these duties are adequately performed remains with the PI/Laboratory supervisor*. The PI/laboratory supervisor is responsible for:

1. Training all laboratory personnel to work safely with hazardous materials. This includes ensuring that they attend any mandatory trainings, review the hazard assessment, read and sign the group Chemical Hygiene Plan, and document this training on the Training Needs Assessment form.

2. Completing a hazard assessment for their laboratory using the online ASSESSMENT tool as well as recertifying the assessment every three years, ensuring the lab roster is up to date and that all lab members have acknowledged the hazard assessment and completed PPE training. Completing all required Standard Operating Procedures as determined by the contents of their chemical inventory. Implementing the necessary controls as guided by this process. Ensuring that lab personnel notify the PI in writing in advance of deviating significantly from these published procedures and assessments. Examples of significant changes include change in

objectives, change in experimental conditions, change in required PPE, and reduction or elimination of administrative and/or engineering controls

3. Providing laboratory workers continuous access to the Chemical Hygiene Plan, either hard copy or electronic, and ensuring that the group-specific materials (contact information, standard operating procedures, etc.) are current and updated annually.

4. Knowing all applicable health and safety rules and regulations, training and reporting requirements associated with chemical safety for regulated substances (Controlled Substances, Regulated Carcinogens, Select Agents (toxins), Homeland Security Chemical Facility Anti-Terrorism Standard chemicals of interest, etc.)

5. Monitoring the safety performance of laboratory workers and visitors, and enforcing policies and rules.

6. Promptly disposing of used, excess or unwanted hazardous chemicals following UC Santa Barbara, state and federal waste disposal requirements.

7. Addressing any findings arising from the Laboratory Safety Review process in the time allotted for the priority level of the finding.

8. Promptly reporting all accidents, injuries and fire extinguisher use to EH&S. For injuries, also completing all worker's compensation reporting requirements.

9. Informing facilities personnel and outside contractors of potential workplace-related hazards when they are required to work in the laboratory space. This includes identifying and removing potential hazards to provide a safe environment for repairs and renovations.

10. Assigning one or more responsible persons the requirements listed above if the PI/Laboratory Supervisor will be on extended leave (> 2 weeks).

Responsibilities of Environmental Health and Safety

EH&S is responsible for administering and overseeing institutional implementation of the Laboratory Safety Program. The Chemical Hygiene Officer (CHO) has primary responsibility for ensuring the implementation of all components of the CHP. The Fire Marshal is responsible for plan review, construction inspections, fire clearance, fire prevention inspections, testing and consultative services related to fire prevention. In case of life safety matters or immediate danger to life or health (IDLH), the Director of EH&S or designee has the authority to order immediate cessation of the activity until the hazardous condition is abated. EH&S provides technical guidance to personnel at all levels of responsibility on matters pertaining to laboratory use of hazardous materials.

The CHO is responsible for:

1. Informing PI/Laboratory Supervisors of all health and safety requirements and assisting with the selection of appropriate safety controls, including appropriate laboratory practices, personal protective equipment and engineering controls for the scope of work being conducted.

2. Managing the Laboratory Review Program. Consulting with the EH&S laboratory safety specialists on the results of their reviews, and necessary steps to abate hazards that may pose a risk to life or safety upon their discovery.

3. Assisting PI/Laboratory Supervisors with hazard assessments, upon request.

4. Assisting the PI/Laboratory Supervisors with the development of SOPs, upon request.

5. Helping to develop and implement appropriate chemical hygiene policies and practices.

6. Having working knowledge of current health and safety rules and regulations, training, reporting requirements, and standard operating procedures associated with regulated substances.

7. Providing technical guidance and investigation for laboratory accidents, injuries and near misses.

8. Reviewing and evaluating the effectiveness of the campus-wide portions of the CHP at least annually, and updating it as appropriate.

9. Providing consultation to the Chemical and Laboratory Safety Committee in the development and implementation of appropriate chemical hygiene policies and practices, and the development of SOPs and SOP templates.

The Chemical Hygiene Officer for the departments of: Chemistry & Biochemistry, Materials, Chemical Engineering and Electrical and Computer Engineering is Nikolai Evdokimov (nevdokimov@ucsb.edu)

The Chemical Hygiene Officer for all other departments is Hector Acuna (hector.acuna@ucsb.edu).

The Fire Marshal is responsible for:

1. Ensuring that the campus complies with California statutes, and fire and life safety rules and regulations of the California State Fire Marshal as adopted or referenced in Title 19 and Title 24 (Parts 2m3m4m5 and 8) of the California Code of Regulations.

2. Inspecting campus facilities, processes and fire protection systems to ensure conformance with State statutes, rules, regulations, and UC fire safety policy.

3. Providing training in fire prevention and use of fire extinguishers.

The Campus Fire Marshal is James White (james.white@ucsb.edu).

Responsibilities of the Chemical and Physical Hazard Safety Committee

The Chemical and Physical Hazards Safety Committee is empowered to promote a safe working environment with respect to chemical and physical hazards in all research and teaching laboratories on campus. It would advise and report to the Chancellor through the Vice Chancellor of Research. The physical hazards covered by this committee include all such hazards not covered by another safety committee, e.g. radioactive materials. These hazards include but are not limited to: electrical hazards, magnetic fields, lasers, extreme temperatures, pressure and vacuum, kinetic energy and noise.

The Chemical and Physical Hazard Safety Committee is responsible for:

Immediate/Emergency functions:

1. Convene with urgency upon the occurrence of an incident or near-miss in order to analyze the situation and advise on immediate actions necessary to mitigate the risk until long-term corrections are in place.

2. Execute formal escalation protocols to address cases of known but uncorrected noncompliance with Federal/State/local safety regulations as well as UC and UCSB safety related policies.

Administrative functions

1. To review, edit and approve annual updates to the campus Chemical Hygiene Plan (CHP) generated by the Research Safety Division of EH&S

2. Develop, recommend, update and maintain policies and procedures applicable to chemical and physical hazard safety. To enable this process, the committee will:
    a. Receive and review summary reports from EH&S laboratory safety inspections, near miss reports and incident reports.
    b. Review findings of inspectors from outside agencies including state and federal regulatory authorities.
    c. Receive input from individual faculty and researchers.

3. Establish formal escalation protocols to address cases of known but uncorrected noncompliance with Federal/State/local safety regulations as well as UC and UCSB safety related policies.

4. Establish and review strategies to ensure adequate surveillance, hazard identification and risk assessment of laboratory activities related to chemical and physical hazards.

5. Design review of new and renovated laboratory space.

Responsibilities of Campus Administration

The Chancellor and Vice Chancellors are responsible for the implementation of UC Santa Barbara's Environmental Health and Safety Policy on campus property. Deans, Directors, and Department Chairs are responsible for establishing and maintaining safety programs in their area to ensure they are providing a safe and healthy work environment.

Other UC Santa Barbara Safety Programs

Given the breadth of research at UCSB, there are other campus safety programs and regulations that can apply to a given operation. Affected individuals should contact these program managers for further information:

Injury and Illness Prevention Program: The "umbrella" OSHA-required worker safety program that applies to all campus workers, regardless of work activities. There is significant overlap between IIPP elements and this manual as relates to lab work, particularly the training and inspection components.

Biological Safety Program: Biological Use Authorizations; Aerosol Transmittable Diseases; Blood borne Pathogens; Medical Waste Management

Radiation Safety Program: Oversight of radioactive materials; radiation-producing machines, magnets and lasers

Chemical Hazard Communication Program: Safety Data Sheets (formerly MSDS); chemical labeling (for labs, much of the HazCom program is superseded by the CHP program – see SDS pg. in Sec. II)

Research Diving and Boating Safety Program: Oversight of research projects involving SCUBA and small boats

Field Research Safety: Training and resources for research field work.

Controlled Substance Program: Oversight of research activities using State/Federal regulated narcotic and non-narcotic drugs

Fire Protection Programs: Includes fire extinguisher training for lab workers, oversight and inspections of fire alarms, sprinklers and other fire protection infrastructure, plus State Fire Marshal approval of plans for lab construction.

Animal Care and Use: Oversight of care and use of animals used in campus research activities

Respiratory Protection Program: Per Cal/OSHA regulations and UCSB Campus Policy, all UCSB personnel who use respiratory protection equipment including filtering facepiece respirators (dust masks) shall be included in the UCSB Respiratory Protection Program.

Confined Space Program: Campus/OSHA requirements and procedures for entering Permit Required Confined Spaces

Indoor Air Quality Program: Response to concerns regarding IAQ within and around campus buildings, especially as relates to health and comfort of building occupants

Hearing Conservation Program: Personnel exposed to occupational noise levels exceeding an 8-hr time-weighted average of 85 dBA must be enrolled in this UCSB/OSHA program

Heat Illness Prevention Program: Establishes campus/OSHA requirements and procedures for individuals who perform outdoor work

Ergonomics Program: Assessments and trainings designed to analyze and evaluate an employee's workspace, equipment, body mechanics, posture, and work flow to promote a more efficient, productive worker and prevent musculoskeletal injuries.

Chapter 2: Training and Outreach Programs

On-Boarding Requirements for New Researchers

Effective training is critical to facilitating a safe and healthy work environment and preventing laboratory accidents. All PI/Laboratory Supervisors must participate in formal safety training and ensure that all their employees have appropriate safety training before working in a laboratory, per UC policy. At UC Santa Barbara, these new researcher training requirements are satisfied by completing the following:

Fundamentals of Laboratory Safety

This is the initial training course that is required before entry into the laboratory is allowed. It can be taken live or online. Live classes are offered in the fall for all incoming graduate students, and every two months year-round. The online class is accessed through the UC Santa Barbara Learning Center. Instructions on how to activate your NetID and register for the class are found here. This course covers the following:

- Review of laboratory rules and regulations, including the Chemical Hygiene Plan.
- Recognition of laboratory hazards.
- Types of engineering controls and personal protective equipment.
- Signs and symptoms associated with exposures to hazardous chemicals.
- Chemical exposure monitoring.
- Procedures for disposing of chemical waste.
- Fire safety and emergency procedures.

The primary difference in content between the live and online class is that the live class includes hands-on fire extinguisher training. Otherwise, the two classes are considered equivalent by EH&S. PI/Laboratory Supervisors and/or departments may however choose to require the live class over the online class. Whichever class is taken, there is an online refresher course required every three years. Those due for the refresher class will get an automated email from the Learning Center.

Laboratory Specific Hazard Assessment Review (ASSESSMENT Online Tool)

Identifying hazards in the workplace is the fundamental first step in developing the appropriate controls for a safe workplace. Conversely, it is impossible to protect oneself from risks in the workplace if the hazards present have not been fully identified and understood.

At UC Santa Barbara, the online tool for identifying hazards in the laboratory is called ASSESSMENT. This tool allows the PI/Laboratory Supervisor to:

- Assign members to a lab group.
- Determine hazards that are present in the lab through a set of guided questions.
- Easily communicate laboratory hazards to group members.
- Identify the proper personal protective equipment (PPE) to be used.

It allows group members to:

- View potential hazards present in the laboratory.
- Receive a list of proper PPE to be used in their lab setting, and a voucher for obtaining the PPE for free.
- Receive training on that PPE.

The PPE distribution center at UC Santa Barbara is located in the Chemistry building storeroom/receiving area (building 557, room 1432). The full process for obtaining PPE is outlined here.

Laboratory-Specific Safety Orientation

All new researchers must receive a day-one laboratory safety orientation per UC policy. This orientation includes emergency procedures and location of emergency equipment, Injury and incident reporting procedures, engineering control use (fume hoods, etc.), a review of the Chemical Hygiene Plan and group specific SOP’s, physical hazard training (e.g. cryogens, high voltage, etc.) PPE use and waste disposal procedures. These lab-specific trainings should be conducted by the PI/Laboratory Supervisor or an experienced research group member who is familiar with the hazards present in the laboratory.

Additionally, any other training requirements should be assessed at this time. This includes use of radioactive materials, radiation producing machines, lasers, biological hazards, controlled substances, etc. These are formal classes that are conducted by EH&S staff.

All of the above training needs and documentation of receipt of that training must be kept on the Training Needs Assessment form. This form is in checklist format to assist the PI/Laboratory Supervisor in determining what trainings that individual needs. Generally, one form per researcher is generated and kept in the research group’s files, although some shared facilities use modified but compliant approaches.

The Laboratory Safety Review Program

Environmental Health and Safety visits each lab space at least once per year. The main program through which these visits are conducted is the Laboratory Safety Review Program. This process consists of the following steps:

1. An EH&S staff member will reach out to each research group and schedule a meeting time with the PI/Laboratory Supervisor or a delegate.

2. The EH&S staff member and the PI/delegate will review various elements of the group’s safety program: standard operating procedures, training records, walk-through of the physical space, etc.

3. A report will be sent to the PI/Laboratory Supervisor via an email directing them to log into our online INSPECT tool.

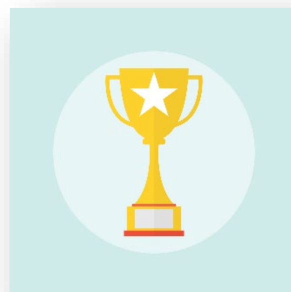
4. A follow-up visit will then be scheduled so that EH&S can validate and assist with the resolution of any findings.

Laboratories with Biological and/or Radiological hazards will also receive independent targeted visits from the Biosafety Officer and/or the Radiation Safety Officer.

Additionally, it is strongly recommended that employers (PI's) conduct regular self-inspections of their workspaces. To assist with this, EH&S has developed this Self-Inspection Checklist.

Incentive Programs and Targeted Trainings

Incentive Program



The Research Safety Incentive Program provides EH&S the opportunity to recognize the contribution of those laboratories or individuals that have improved the safety culture. This program has two facets, described below.

On the Spot Safety Award

We will recognize lab workers who are proactive in furthering and modeling behavior that is illustrative of a positive laboratory safety culture such as:

- Wearing proper protective equipment.
- Reporting a near miss that could have resulted in injury/illness.
- Recommending a meaningful, innovative improvement for a safer work area.

On-the-Spot Awards are presented to researchers by EH&S staff as the behavior is observed, and throughout the year. They consist of a small gift such as a gift card for a food or beverage establishment.

Laboratory Safety Recognition

We will recognize lab groups for their effort and devotion to safety. This includes those who display a strong safety culture as determined by Laboratory Safety Reviews as well as by regular informal interactions with EH&S staff.

EH&S will arrange a lunch or breakfast meeting with the lab group to recognize their efforts and allow for open discussion of any concerns, issues, or best practice ideas. We will also feature the lab group in the EHS newsletter: Safety Slick.

Targeted Training

The goal of UC Santa Barbara is to achieve more than simple regulatory compliance. This campus strives toward fostering a strong, positive safety culture by integrating safety as an essential element in the daily work of laboratory researchers. EH&S's time and attention is therefore dedicated to providing assistance and guidance to lab groups on growing and optimizing their safety practices. We will provide hands on (refresher) trainings to those groups showing a need in a specific area. For example, if a lab group has continued issues of poor hazardous waste practices (e.g. open unattended containers, missing/incomplete waste label, etc.) we will arrange for a training in the lab. *Additionally, EH&S is available to consult and meet with lab groups to discuss any relevant safety topic/issue at the researchers' request.* By meeting with lab groups and providing trainings as needed, EH&S hopes to foster a positive atmosphere for communication, education, advice, discussions, and the sharing of progress. Please feel free to contact your department's EH&S representative if you would like us to meet your group to discuss a safety topic or to provide a training:

Andrea Tufekcic (andreatufekcic@gmail.com) for:

Chemistry & Biochemistry
Earth Science
Physics
Electrical and Computer Engineering
Molecular, Cell and Developmental Biology
Materials Research Laboratory
Neuroscience Research Institute

Jose Diaz (jose_diaz@ucsb.edu) for:

Anthropology
Bren School
Chemical Engineering
CNSI
Ecology, Evolution and Marine Biology
Geography
Materials
Mechanical Engineering
Natural Reserve System
Psychology

Marine Science Institute labs contact **Cary Haack (carlyhaack@ucsb.edu)**.

Chapter 3: Handling Hazardous Chemicals

Chemical Hazard Classes

The Globally Harmonized System (GHS) of hazard communication was developed to identify to the user of a material both the hazards and the risks associated with it. This system recognizes thirty one classes of chemical hazards. These classes fall into three broad categories: physical hazards, health hazards, and environmental hazards. In addition, the severity of the hazard is assigned a numerical category of 1-4, with 1 being the most severe. These categories are rigorously defined for each hazard class in the OSHA publication Hazard Communication: Hazard Classification Guidance for Manufacturers, Importers and Employers. A material may exhibit more than one hazard. A material's hazard class(es) determine how it is stored and handled, what special equipment may be needed, and what procedures need to be established to ensure safe handling. GHS information can be found on all commercial chemical labels printed after 2015, and the Safety Data Sheet (SDS) associated with that chemical. Any release of these materials to the environment must be reported to Environmental Health & Safety Immediately. Listed below are the hazard classes, along with the associated GHS pictogram.

Reactive and Unstable Chemicals.

Reactive and unstable chemicals are those that may decompose violently, polymerize or self-react under conditions of shock, friction, temperature, pressure, light, or contact with other materials, resulting in the release of large volumes of gas or heat. Therefore, storage of these materials in such a way as to protect from these conditions is of the utmost importance. Additionally, they must be stored segregated from other materials in cabinets or refrigerator/freezer designed for storing flammable and reactive chemicals.
Examples: explosives, peroxides, azo and azido compounds.

Oxidizers

Oxidizers are chemicals that cause or increase the intensity of the combustion of other materials. They can do so by delivering oxygen atoms, or by other means. Oxidizers should be stored in a cool, dry place and kept away from flammable and combustible materials such as organic chemicals, wood and plastic, and away from reducing agents.
Examples: Oxygen, Bromine, Nitric Acid, Hydrogen Peroxide.

Flammable Chemicals

Flammable liquids include those chemicals that have a flashpoint of less than 100 °F. These materials must be stored in flammable storage cabinets, with no more than 10 gallons/room total outside of storage (including flammable organic waste). Flame-resistant laboratory coats must be worn when working with large volumes of flammable materials (>1L) and/or with procedures where a significant fire risk is present, such as working with an open flame or pyrophoric materials. These materials constitute a significant immediate threat and should be treated with particular care, given the comparatively large quantities that can be present in a laboratory setting. Particular attention should be given to preventing static electricity and sparks when handling flammable liquids. This can be accomplished in part by appropriately grounding metal flammable storage cabinets and any metal dispensing drums inside them, as well as the receiving container.

Examples: Diethyl Ether, Acetone, Hexane

Pyrophoric Materials are a class of materials that spontaneously ignite when in contact with air and require laboratory-specific training. Flame-resistant laboratory coats and hand protection must be worn when handling these chemicals**. Before working with pyrophoric materials, individuals must demonstrate knowledge of the appropriate methods to handle, transfer, and quench the material being used.** Templates for generating Standard Operating Procedures for pyrophoric materials handling can be found in the UC Santa Barbara SOP Template Library.
Examples: Grignard reagents, organolithium reagents, silane.

Water Reactive Chemicals can evolve flammable or toxic gas when they come into contact with water *or atmospheric moisture*. Like pyrophoric materials, this reaction may produce enough heat to ignite any flammable gases thus generated. Therefore, they should be stored away from water and other sources of protons, such as acidic materials.
Examples: potassium metal, sodium metal

Corrosives

As a health hazard, corrosive substances cause destruction of, or alterations in, living tissue by chemical action at the site of contact. Major classes of corrosive substances include:

- Strong acids: sulfuric, nitric, hydrochloric, etc.
- Strong bases: sodium hydroxide, potassium hydroxide, ammonium hydroxide.
- Dehydrating agents: phosphorus pentoxide, calcium oxide, etc.
- Oxidizing agents: hydrogen peroxide, chlorine, bromine, etc.

Symptoms of exposure via inhalation include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea and vomiting. For eye exposure, symptoms include pain, redness, tearing and blurring of vision. For exposure to the skin, symptoms may include pain, redness, inflammation, blistering and burns.

As a physical hazard, corrosive substances may degrade materials they come in contact with and may react violently. It is important to review information regarding the materials they may corrode, and their reactivity with other substances. They should be stored in chemically-compatible secondary containers, and should be segregated from other classes of materials.

Irritants and Sensitizers

Irritants are non-corrosive chemicals that cause reversible inflammatory effects on living tissue by chemical action at the site of contact. A wide variety of organic and inorganic compounds, including many chemicals that are in a powder or crystalline form, are irritants. Consequently, eye and skin contact with all laboratory chemicals should be avoided. Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.
Examples: Chlorine, methylene chloride, formaldehyde

Sensitizers are chemicals which cause a substantial proportion of exposed people or animals to develop an allergic reaction after repeated exposure to the chemical. Symptoms can include all of the symptoms normally associated with allergic reaction, including life-threatening anaphylaxis.
Examples: diazomethane, chromium, nickel, formaldehyde, isocyanates, many phenol derivatives.

Compressed Gases and Cryogenic Liquids

Compressed gas cylinders are pressurized vessels that pose both physical and health hazards additional to those of the gases they contain, and therefore must be handled and stored carefully. For example, even an inert, non-toxic gas like nitrogen poses an asphyxiation risk if the pressure in a nitrogen tank is released suddenly enough to overwhelm room ventilation. Additionally, a cylinder rupture (generally occurring at the weak spot in the cylinder located and the connection between the body of the cylinder and the valve) can lead to the cylinder becoming a projectile and endangering personnel, equipment and structures. Additionally, the gases themselves may have hazards associated with them such as flammability (hydrogen), toxicity (ammonia), reactivity (fluorine) and pyrophoricity (silane). **Highly toxic and pyrophoric gases are some of the most dangerous materials found in the laboratory. A gas-specific Standard Operating Procedure must be developed for these materials in conjunction with the campus Chemical Hygiene Officer**. *Examples of highly toxic gases: hydrogen fluoride, methyl bromide, nickel carbonyl, phosgene.*

All compressed gas cylinders must be stored with the safety cap in place when not in use. Cylinders must be held in place by a welded-link steel chain attached to mounts bolted into the structure, or chained in a cylinder storage rack. Specific gases may have additional storage requirements. Refer to the 'Gases under pressure' SOP template for more information.

Publication date January 2023

Cryogenic liquids such as liquid nitrogen and helium pose similar asphyxiation risks as their compressed gas counterparts. Additional hazards include frost burn of the skin and eyes. Always use appropriately insulated gloves when handling cryogenic liquids. Face shields may be needed, in addition to safety glasses/goggles, in cases where splashing may occur or when cryovials are being handled as they may explode when warmed. As cryogen dewars are at low pressure and have protective rings around the regulator, they do not need to be chained in storage.

Particularly Hazardous Substances

Three classes of hazardous chemicals are defined by Cal/OSHA as 'Particularly Hazardous Substances' (PHS). These classes are: *carcinogens, reproductive toxins, and acute toxins*. (It is important to note that many substances present in the laboratory are new chemical entities that have not been subjected to any kind of toxicity or carcinogenicity testing, and should be handled with that in mind.) Special provisions must be established and documented in laboratory SOPs to prevent the exposure of laboratory personnel to these materials, including:

- Establishment of designated areas
- Use of containment devices (e.g. fume hoods)
- Procedures for contaminated waste disposal
- Decontamination procedure.

These requirements will be discussed in the Hazard Controls section.

Carcinogens

Carcinogens are chemical or physical agents that cause cancer. Generally they exhibit chronic toxicity; that is, they cause damage after repeated or long-duration exposure, and their effects may only become evident after a long latency period. Chronic toxins of this kinds are particularly insidious because they may have no immediately apparent harmful effects (also referred to as 'warning properties'). Carcinogenic chemicals are separated into three classes:

- Select Carcinogens
- Regulated Carcinogens
- Listed Carcinogens

Select Carcinogens are materials which have met certain criteria established by the National Toxicology Program (NTP) or the International Agency for Research on Cancer (IARC) regarding the risk of cancer via certain exposure routes. The following references are used to determine which substances are select carcinogens by Cal/OSHA's classification

- Is a Listed Carcinogen
- Annual Report on Carcinogens published by the National Toxicology Program (NTP), 'known to be carcinogens' and 'reasonably anticipated to be carcinogens' lists.

- International Agency for Research on Cancer (IARC), Group 1 'carcinogenic to humans, Group 2A 'probably carcinogenic to humans, and Group 2B 'possibly carcinogenic to humans'.
- Is a Regulated Carcinogen.

Regulated Carcinogens are of a higher hazard class than the select carcinogens, and therefore there are additional provisions required for their handling, per Cal/OSHA 8 CCR Article 110. This may include personal exposure monitoring. When working with regulated carcinogens, it is particularly important to review and effectively apply the Standard Operating Procedure for PHS's. If it is found that a laboratory has exceeded the Cal/OSHA defined permissible exposure limit (PEL) for a regulated carcinogen, extensive additional regulatory requirements will apply to that laboratory. The regulated carcinogens are:

- Acrylonitrile
- Arsenic and inorganic arsenic compounds
- Asbestos
- Benzene
- 1,3-Butadiene
- Cadmium metal and cadmium compounds
- Chromium(VI) compounds
- Methylenedianiline (MDA)
- Vinyl chloride
- Coke oven emissions
- 1,2-Dibromo-3-chloropropane (DBCP)
- Ethylene dibromide (EDB)
- Ethylene oxide (EtO)
- Formaldehyde gas and solutions
- Lead and inorganic lead compounds
- Dichloromethane
- 4,4'-Methylene-bis(2-chloroaniline) (MBOCA)
- All Listed Carcinogens

Listed Carcinogens are the thirteen chemicals listed in 8 CCR §5209. These chemicals are considered to pose the highest carcinogenicity hazard. They have many additional requirement for use beyond those required for regulated carcinogens. Given these strict regulatory requirements for use, handling and storage, the campus Chemical Hygiene Officer must be contacted before any work is initiated. Purchases of these materials will also be routed to the Chemical Hygiene Officer for approval. The Listed Carcinogens are:

- 2-acetylaminofluorine
- 4-Aminodiphenyl
- Benzidine and its salts
- 3,3'-Dichlorobenzidine and its salts
- 4-Dimethylaminobenzene
- Alpha-naphthylamine
- Beta-naphthylamine
- 4-Nitrobiphenyl
- N-Nitrosodimethylamine
- Beta-Propiolactone
- Bis-chloremethyl ether
- Methyl chloromethyl ether (MOM-Cl)
- Ethyleneimine

__Reproductive Toxins__

Reproductive toxins include any chemical that may affect reproductive capabilities, including causing chromosomal damage (mutagenesis), effects on fetuses (teratogenenesis), and adverse effects on sexual function and fertility. Reproductive toxins can affect the reproductive health of both men and women if proper procedures and controls are not used. For women, exposure to reproductive toxins during pregnancy can cause adverse effects on the fetus; these effects include embryo lethality (death of the fertilized egg, embryo or fetus), malformations (teratogenic effects) and postnatal defects. For men, exposure can lead to sterility.

Examples of embryotoxins include thalidomide and certain antibiotics such as tetracycline. Women of childbearing potential should note that embryotoxins have the greatest impact during the first trimester of pregnancy. Because a woman often does not know that she is pregnant during this period of high susceptibility, special caution is advised when working with all chemicals, especially those rapidly absorbed through the skin (e.g. formamide). Pregnant women and women intending to become pregnant should consult with their laboratory supervisor and their physician before working with substances that are suspected to be reproductive toxins.

Mutagens are a class of materials that cause a change in the genetic material of a living cell. As such, they effect changes that can potentially lead to both reproductive toxicity and the development of cancer.

Acute Toxins

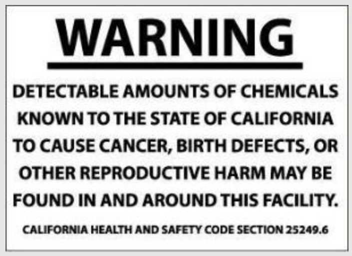
Acute toxins are substances that may be fatal as a result of a single exposure, or exposures of short duration, via one or more of three routes, defined as:

- ORAL: A chemical with a median lethal dose (LD_{50}) of 50 mg or less per kg of body weight.
- DERMAL: A chemical with a median lethal dose (LD_{50}) of 200 mg or less per kg of body weight.
- INHALED: A chemical that has a median lethal concentration (LC_{50}) in air of 500 ppm by volume or less of gas, 2.0 mg per liter or less of vapor, or 0.5 mg per liter or less of mist or dust, when administered by continuous inhalation for 4 hours (or less if death occurs within 4 hours)

Substances or mixtures classified by their manufacturer under GHS as Category 1 or 2 for acute toxicity meet this definition, and the associated hazard statement specifies that they are “fatal” via one or more of the three exposure routes.

Chemicals Known to the State of California to Cause Cancer or Reproductive Toxicity

The Safe Drinking Water and Toxic Enforcement Act of 1986, also known as Proposition 65, requires the state to publish a list of chemicals known to cause cancer or reproductive toxicity. It also requires businesses to provide warnings to Californians about significant exposure to the chemicals on the list. These chemicals can be in the products that Californians purchase, in their homes or workplaces, or that are released into the environment. The University of California, as a government agency, is exempt from the warning requirements of this law.



Toxic Substances

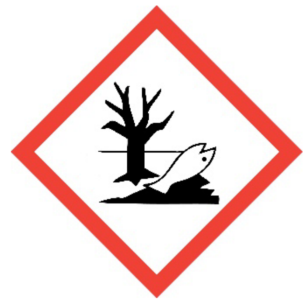
Substances which may cause toxicity as the result of a single exposure, but are typically not fatal in small does, are considered toxic. Substances classified as Category 3,4 and 5 under GHS for acute toxicity meet this definition*, and are not considered particularly hazardous substances (PHS)*.Category 3 substances are associated with the skull-and-crossbones pictogram. Category 4 and 5 are associated with the exclamation mark pictogram.

Substances which cause damage to target organs are also considered to be toxic, and are indicated under GHS by the same health hazard pictogram as are carcinogens and reproductive toxins. These include:

- Hepatotoxins: Substances that damage the liver. *Examples: nitrosamines, carbon tetrachloride.*
- Nephrotoxins: Substances that damage the kidneys. *Examples: certain halogenated hydrocarbons, ethylene glycol (antifreeze).*
- Neurotoxins: Substances that damage the nervous system. *Examples: mercury, acrylamide, carbon disulfide*.
- Hematopoetic agents: Substances that decrease hemoglobin function and deprive the body tissues of oxygen. *Examples: carbon monoxide, cyanide ion*.
- Respiratory toxins: Substances that damage the lung tissue. *Examples: asbestos, silica*.

Symptoms of exposure to toxic and acutely toxic materials vary. Those working with these materials should review the SDS for the specific material being used, and should take special note of the symptoms of exposure.

Chemicals Hazardous to the Environment



Materials with demonstrated toxicity to aquatic organisms are classified as toxic to the environment. It is particularly important that such materials be stored in a manner which minimizes the risk of accidental release, and that they be disposed of as hazardous waste. As with all hazardous chemicals, any release to the environment must be reported to Environmental Health and Safety immediately.

Peroxide-Forming Chemicals

Materials that may form potentially explosive peroxides are not classified under GHS, but are of significant concern. These peroxides are much more shock-sensitive than TNT, and are also sensitive to sparks or other accidental ignition. Many of these chemicals are common organic solvents and care must be taken in their use and storage. There are no specific regulations that address the handling, classification of, or control methods for peroxidizable materials. The information included here is considered best practice and is based on Prudent Practices in the Laboratory, Chapters 4 and 6.

Some moieties that are known to form peroxides include:

- Primary and secondary alkyl ethers
- Compounds with benzylic hydrogens
- Compounds with allylic hydrogens
- Compounds with a tertiary C-H group
- Conjugated polyunsaturated alkenes and alkynes
- Compounds containing secondary or tertiary C-H groups adjacent to an amide.

All peroxide-forming chemicals should be stored in airtight containers in a cool, dry area. If the container is transparent it should also be protected from light. Inventories should be carefully controlled, with the date of receipt and the date of opening marked on the label. There are three classes of peroxidizable chemicals, each with its own set of storage requirements. The three tables below are not comprehensive lists of each class, but are examples of each more commonly found in the laboratory.

Class A: Chemicals that form explosive levels of peroxides without concentration.

These chemicals form peroxides upon exposure to air, and continue to build peroxides to potentially dangerous levels. ***They are especially dangerous and must be discarded within 3 months of receipt or formation.***

Class A Peroxide-Forming Chemicals:

Isopropyl Ether	Sodium Amide
Butadiene liquid	Tetrafuoroethylene
Chlorobutadiene (chloroprene)	Divinyl Acetylene
Potassium Amide	Vinylidine Chloride
Potassium Metal	

Class B: Chemicals that are a peroxide hazard on concentration.

These chemicals form peroxides upon exposure to air, but develop a low equilibrium concentration. These chemicals become dangerous only when condensed via evaporation or distillation. The peroxide becomes concentrated because it is less volatile than the parent chemical. Note that with low boiling-point solvents such as diethyl ether, this concentration can occur while in storage. Thus, old bottles of peroxidizable low-boiling solvents can become dangerously shock-sensitive without any active effort to condense the liquid. Some of these materials are sold with inhibitors added to them, which does increase their shelf-life. However, users must be aware that distillations, condensations and other purification techniques will remove these stabilizers.

From the date of opening, ***Class B chemicals with inhibitors can be stored for 12 months, without inhibitors they can be stored for 6 months***. After this point, they should be discarded. All Class B chemicals past the manufacturer's expiration date should be discarded.

Class B Peroxide-Forming Chemicals

Acetal	**Dioxane**
Cumene	Ethylene Glycol Dimethyl Ether (Glyme)
Cyclohexene	Furan
Cyclooctene	Methyl Acetylene
Cyclopentene	Methyl Cyclopentane
Diacetylene	Methyl Isobutyl Ketone
Dicyclopentadiene	**Tetrahydrofuran**
Diethylene Glycol Dimethyl Ether (diglyme)	Tetrahydronaphthalene
Diethyl ether	Vinyl ethers

Common laboratory solvents in bold

Class C: Unsaturated monomers that may autopolymerize as a result of peroxide accumulation

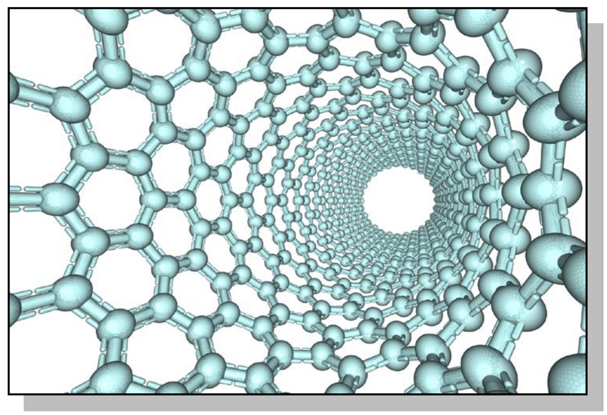
This class of compounds consists of inhibitor free monomers designed to undergo free-radical polymerization. Upon exposure to air, these compounds can form peroxides that then violently polymerize. Often they are sold with a polymerization inhibitor added. These inhibitors require the presence of oxygen to function, and therefore these products should not be stored under an inert atmosphere. As this can cause confusion, please refer to the manufacturer instructions and/or the SDS for storage requirements. ***Pure, uninhibited materials must only be stored for 5 days or less. Inhibited material may be stored for 12 months***.

Class C Peroxide-Forming Chemicals

Acrylic Acid	Styrene
Butadiene gas	Vinyl Acetate
Chlorotrifluoroethylene	Vinyl Chloride
Ethyl Acrylate	Vinyl Pyridine
Methyl Methacrylate	

If you find a container of peroxidizable material of unknown age or origin, isolate the immediate area and call EH&S at **(805) 893-3194**.

Nanomaterials



The increasing use of nanomaterials in research labs warrants consideration of the hazards they may pose. As is the case with many new technologies, the health effects of nanomaterials have not been thoroughly investigated. Consequently, the uncertainty surrounding the health hazards of nanomaterials merits a cautious approach when working with them.

Nanomaterials include any materials or particles that have an external dimension in the nanoscale (1-100 nm). Nanomaterials are both naturally occurring in the environment and intentionally produced. Intentionally produced nanomaterials are referred to as Engineered Nanomaterials (ENM). Materials whose properties do not differ significantly between their nanoscale and larger forms are generally excluded from ENMs. Some examples of ENMs include fullerenes, carbon nanotubes, carbon nanofibers, quantum dots and metal oxide nanoparticles.

The parent compound of the nanomaterial should also be taken into consideration when evaluating the potential hazards associated with exposure (e.g. a highly toxic compound such as cadmium should be anticipated to be at least as toxic and possibly more toxic when used as a nanomaterial). However, even materials which are non-toxic in their bulk phase (e.g. carbon) may display significant toxicity as nanomaterials (e.g. multiwall carbon nanotubes).

Naturally occurring nanomaterials like amorphous silica and carbon black have legal (Cal/OSHA) exposure limits (for these examples 80 mg/m^3 and 3.5 mg/m^3respectively). Currently, there are no legal exposure limits for engineered nanomaterials in the US or internationally. However, NIOSH (National Institute for Occupational Safety and Health) has developed Recommended Exposure Limits (RELs) for just two ENMs: carbon nanotubes (7 $\mu g/m^3$) and nano-titanium dioxide (0.3 $\mu g/m^3$).

Nanomaterials are categorized by the potential risk of exposure they pose to personnel based on the physical state of the materials and the conditions in which they are used. In general, the risk of exposure is lowest when nanomaterials are bound in a solid matrix with little potential to create airborne dust, or when in a non-volatile liquid suspension. The risk of exposure increases when nanomaterials are used as fine powders, are suspended in volatile solvents or gases, or are used in procedures capable of producing aerosols. The Nanotoolkit referenced below divides these materials into 3 categories, and assigns appropriate controls to each (Table 3.1). This allows researchers to develop a Standard Operating Procedure (SOP) for handling their ENM given these factors. In moderate to high exposure risk cases as determined by the Nanotoolkit, it is advisable to reach out to the EH&S Respiratory Protection Program for a consultation, as respiratory protection may be required. Personal Protective Equipment such as gloves should be chosen taking into consideration the nanomaterial as well as other chemicals being used in conjunction with them, such as solvents. Double gloving is advised.

Table 3.1

Risk level	Controls	
Category 1 Low Exposure Potential	Engineering	• Fume Hood or Biosafety Cabinet. Perform work with open containers of nanomaterials in liquid suspension or gels in a laboratory-type fume hood or biosafety cabinet, as practical.
	Work Practices	• Storage and labeling. Store in sealed container and secondary containment with other compatible chemicals. Label chemical container with identity of content (include the term "nano" in descriptor). • Preparation. Line workspace with absorbent materials. • Transfer in secondary containment. Transfer between laboratories or buildings in sealed containers with secondary containment. • Housekeeping. Clean all surfaces potentially contaminated with nanoparticles (i.e., benches, glassware, apparatus) at the end of each operation using a HEPA vacuum and/or wet wiping methods. DO NOT dry sweep or use compressed air. • Hygiene. Wash hands frequently. Upon leaving the work area, remove any PPE and wash hands, forearms, face, and neck. • Notification. Follow institution's hazard communication processes for advanced notification of animal facility and cage labeling/management requirements if dosing animals with the nanomaterial
	PPE	• Eye protection. Wear proper safety glasses with side shields (for powders or liquids with low probability for dispersion into the air) • Face protection. Use face shield where splash potential exists. • Gloves. Wear disposable gloves to match the hazard, including consideration of other chemicals used in conjunction with nanomaterials (refer to Table 1. Glove Choices for Nanomaterials) • Body protection. Wear laboratory coat and long pants (no cuffs). • Closed toe shoes.
Category 2 Moderate Exposure Potential	Engineering	• Fume Hood, Biosafety Cabinet, or Enclosed System. Perform work in a laboratory-type fume hood, biosafety cabinet* (must be ducted if used in conjunction with volatile compounds), powder handling enclosure, or enclosed system (i.e., glove box, glove bag, or sealed chamber).
	Work Practices	• Category 1 Work Practices. Follow all work practices listed for Category 1. • Access. Restrict access. • Signage. Post signs in area. • Materials. Use antistatic paper and/or sticky mats with powders.
	PPE	• Category 1 PPE. Wear all PPE listed for Category 1. • Eye protection. Wear proper chemical splash goggles (for liquids with powders with moderate to high probability for dispersion into the air). • Gloves. Wear two layers of disposable, chemical-protective gloves. • Body protection. Wear laboratory coat made of non-woven fabrics with elastic at the wrists (disposable Tyvek®-type coveralls preferred). • Closed toe shoes. Wear disposable over-the-shoe booties to prevent tracking nanomaterials from the laboratory when working with powders and pellets. • Respiratory Protection. If working with engineering controls is not feasible, respiratory protection may be required. Consult an EH&S professional for more information (i.e., N95 respirator, or one fitted with a P-100 cartridge).
Category 3 High Exposure Potential	Engineering	• Enclosed System. Perform work in an enclosed system (i.e., glove box, glove bag, or sealed chamber).
	Work Practices	• Category 2 Work Practices. Follow all work practices listed for Category 2.
	PPE	• Category 2 PPE. Wear all PPE listed for Category 2. • Body protection. Wear disposable Tyvek®-type coveralls with head coverage. • Respiratory Protection. If working with engineering controls is not feasible, respiratory protection may be required. Consult an EH&S professional for more information (i.e., N95 respirator, or one fitted with a P-100 cartridge).

For more information, see:

- The California Nanosafety Consortium of Higher Education's Nanotoolkit: Working Safety with Engineered Nanomaterials in Academic Research Settings,

- The National Institute of Occupational Safety & Health's (NIOSH) General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories, and

- The National Institute of Occupational Safety & Health's (NIOSH) Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes.

Determining Hazard Classes

For materials obtained from outside suppliers, PIs/Laboratory Supervisors may rely on the hazard determination of the manufacturer. However, PIs/Laboratory Supervisors are responsible for making reasonable determinations of the health and/or physical hazards of any *materials produced in their laboratories*.

The term 'hazardous substance' refers to any chemical for which 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 individuals. PIs/Laboratory Supervisors may assume that any chemical of known composition produced in their lab is hazardous if it is listed in the following:

- Cal/OSHA's The Hazardous Substance List: 8 CCR §339, commonly referred to as the Director's List of Hazardous Substances.

- Cal/OSHA's Toxic and hazardous Substances, Air Contaminants: 8 CCR §5155.

- Threshold Limit Values for Chemical Substances in the Work Environment, ACGIH, 2009.

- Fourteenth Annual Report on Carcinogens, NTP, 2016

- Monographs, IARC, WHO

- Chemicals Known to the State to Cause Cancer or Reproductive Toxicity: Proposition 65, 22 CCR §12000,

Any chemical of unknown composition should be presumed to be hazardous. Chemical derivatives of known materials should be presumed to be at least as hazardous as their parent compound. In all such cases, PIs/Laboratory Supervisors should take appropriate steps to prevent exposure.

Chemical Hazard Communication

Employers are required by Cal/OSHA to provide information to their employees about the hazardous substances to which they may be exposed. Below are the main routes by which this information is disseminated.

Chemical Labeling

All chemicals in the laboratory should be properly labeled. Commercial chemicals come with a manufacturer's label which contains the necessary information. Care should be taken not to remove or deface these labels. For containers without manufacturer's labels, the following labeling requirements must be adhered to:

- All containers of hazardous materials must be labeled with the identity of the substance, legibly and in English. Acronyms (e.g. IPA) and chemical formulas alone do not fulfill this requirement.

- The label must contain applicable warning statements (e.g. Flammable, corrosive).

- Particularly Hazardous Substances (PHS) must also be labeled with the specific hazard that meets the definition of PHS (e.g. Acute Toxin, Carcinogen, Reproductive Toxin). Additionally, *the storage area where PHS's are kept must also be labeled with the type of hazard*. These chemicals should be segregated from other chemicals to help with proper access control and hazard identification.

- Peroxide forming chemicals must be labeled with the *date of receipt and the date of opening*.

Safety Data Sheets (SDS)

An SDS must be available for each hazardous substance in a laboratory's chemical inventory. PI's/laboratory Supervisors are responsible for ensuring that all researchers have immediate access to SDS's, and are trained on how to access them, as well as understanding their relevance to the health and safety of the workplace. (SDS format and access requirements are covered in the mandatory EH&S Fundamentals of Laboratory Safety class.) Access may be either physical or digital.

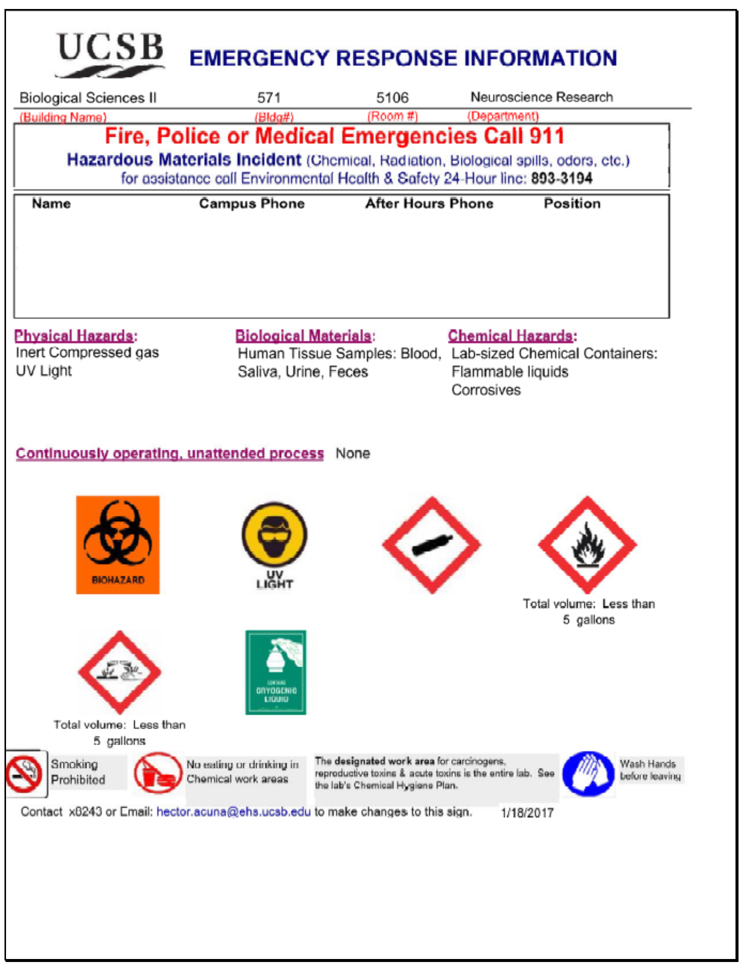
Like the hazard class pictograms, SDS format and content have been standardized by the Globally Harmonized System. Chemical manufacturers are require to provide updated SDS's. The required 16 sections of an SDS are:

1. Identification of the substance or mixture, and of the supplier
2. Hazard Identification

3. Composition/information on ingredients.
4. First Aid measures
5. Firefighting measures
6. Accidental release measures
7. Handling and storage
8. Exposure control/personal protection
9. Physical and chemical properties
10. Stability and reactivity
11. Toxicological information
12. Ecological information
13. Disposal considerations
14. Transport information
15. Regulatory information
16. Other information, including information on preparation and revision of the SDS

Some useful links for accessing SDS's on line are located on the EH&S website.

Figure 3.1



UCSB EMERGENCY RESPONSE INFORMATION

Biological Sciences II	571	5106	Neuroscience Research
(Building Name)	(Bldg#)	(Room #)	(Department)

Fire, Police or Medical Emergencies Call 911

Hazardous Materials Incident (Chemical, Radiation, Biological spills, odors, etc.)
for assistance call Environmental Health & Safety 24-Hour line: **893-3194**

Name	Campus Phone	After Hours Phone	Position

Physical Hazards:
Inert Compressed gas
UV Light

Biological Materials:
Human Tissue Samples: Blood, Saliva, Urine, Feces

Chemical Hazards:
Lab-sized Chemical Containers:
Flammable liquids
Corrosives

Continuously operating, unattended process None

BIOHAZARD

UV LIGHT

Total volume: Less than 5 gallons

Total volume: Less than 5 gallons

CRYOGENIC LIQUID

Smoking Prohibited

No eating or drinking in Chemical work areas

The **designated work area** for carcinogens, reproductive toxins & acute toxins is the entire lab. See the lab's Chemical Hygiene Plan.

Wash Hands before leaving

Contact x8243 or Email: hector.acuna@ehs.ucsb.edu to make changes to this sign. 1/18/2017

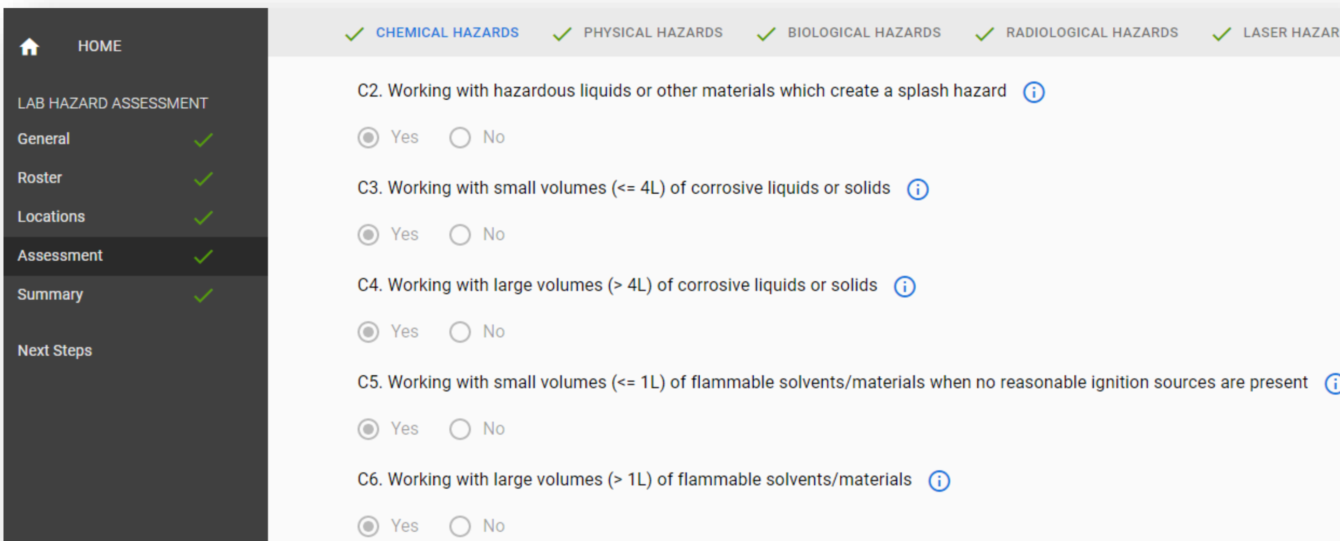
Door Placards

To aid emergency responders, every corridor entrance to laboratories has a placard conveying information regarding the types of hazards within and laboratory emergency contacts (Figure 3.1). The information is updated annually, but laboratories should submit a new EH&S door placard form if the placard becomes out of date at any time.

Lab Hazard Assessment Tool (ASSESSMENT)

As described in the previous chapter, ASSESSMENT, the new laboratory hazard assessment tool, was developed as a method for identifying and communicating the hazards that are present in each laboratory via a set of guided questions (**Figure 3.2**). As such, it is a key component to the hazard communication process for reducing workplace illness and injury

Figure 3.2

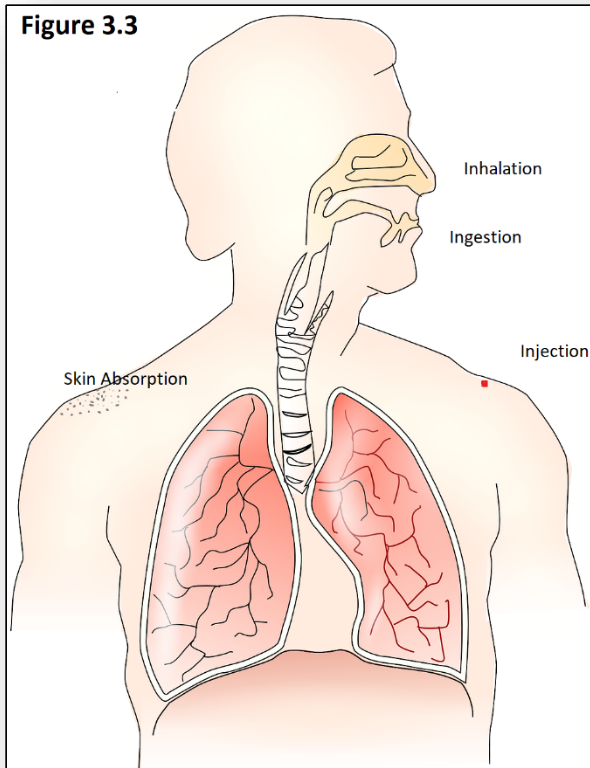


How to Reduce Exposures to Hazardous Chemicals (Hazard Controls)

There are four primary routes of exposure for chemicals that have associated health hazards (Figure 3.3):

1. Inhalation: e.g. breathing in chemical fumes
2. Ingestion: e.g. eating contaminated food in the lab
3. Absorption (through skin or eyes): e.g. chemical splash
4. Injection: e.g. contaminated needle stick or uptake through an existing wound

Figure 3.3

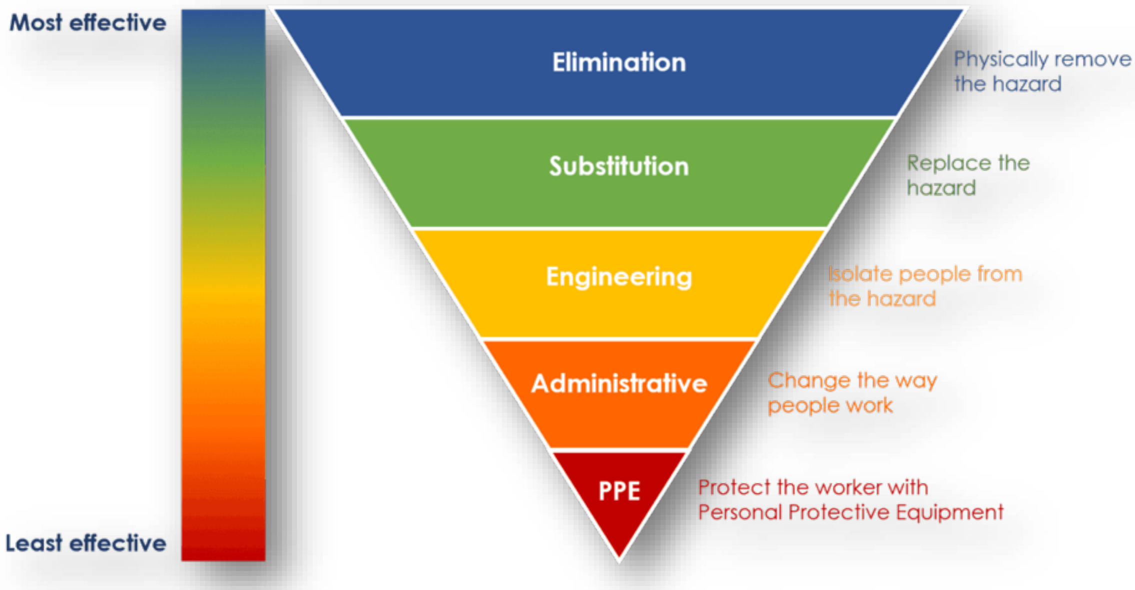


Of these, the most likely route of exposure in the laboratory is by inhalation. Many hazardous chemicals may affect people through more than one of these exposure routes, so it is critical that protective measures are in place for each of the uptake mechanisms.

The methodologies for controlling exposures to hazardous chemicals are termed 'Controls'. Each type of control is designed to reduce the *risk* of interacting with a material and its inherent *hazards*. It requires a carefully considered, multi-tiered system of safety controls to effectively manage the risks associated with exposure to these chemicals. Broadly, safety controls can be divided into four classifications: Elimination, Substitution, Engineering Controls, Administrative Controls, and Personal Protective Equipment.

In figure 3.4, each of these control types are ordered according to their effectiveness. Elements of all of these are used in a layered approach to create a safe working environment. The principles of each of these control types are detailed below.

Figure 3.4: The Hierarchy of Controls



Elimination and Substitution

The only way to reduce to zero the risk of interacting with a particular hazard is to remove that hazard completely. Thus, elimination is considered to be the most effective safety control. As this is often not practical in the laboratory, the next-best approach is to substitute the hazard with something less hazardous. Examples of substitution might include substituting toluene for benzene as a reaction or purification medium.

Engineering Controls

The National Institute of Occupational Safety and Health (NIOSH) states that:

> "Engineering Controls are used to remove a hazard or place a barrier between the worker and the hazard… Well-designed engineering controls can be highly effective in protecting workers and will typically be independent of worker interactions to provide this high level of protection."

Following Elimination and Substitution these controls offer the first line of protection to prevent exposures to hazardous chemicals. As noted in the excerpt above, they require minimal alteration of procedures on the part of the researcher (except in emergency situations) and therefore are less prone to user error than other control methods. A fundamental and very common example is the laboratory fume hood, which is very effective at containing chemical fumes and vapors, and thereby protecting users from inhalation hazards. Other examples of engineering controls include flammable material storage cabinets, snorkels, and general room ventilation.

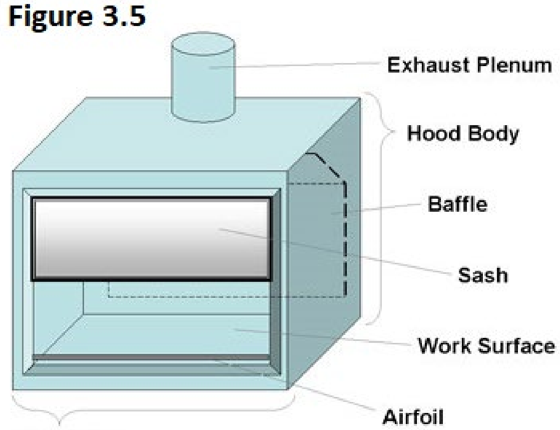
General Laboratory Ventilation

Per California Fire Code and the University of California Lab Safety Design Manual, laboratory spaces where hazardous materials are used or stored have mechanically generated and conditioned supply and exhaust air. The intakes supply outside fresh air, and the exhausts vent 100% to the outside, with no return of fume hood and laboratory general exhaust back into the building. The total volume of exhaust air should meet a minimum of 1 cfm/ft^2, or roughly 6 air changes per hour. Laboratories are kept at negative pressure to adjoining non-laboratory spaces (e.g. the hallway) to prevent the spread of airborne hazards.

Fume Hoods

Chemical fume hoods are the most commonly used local exhaust system on campus, and are one of the most important pieces of equipment used to protect workers from exposure to hazardous chemicals. Other examples of local exhaust systems include vented enclosures for large pieces of equipment or chemical storage, and movable exhaust systems for capturing contaminants near the point of release, a.k.a. snorkels. Figure 3.5 shows the key components of a fume hood.

Figure 3.5



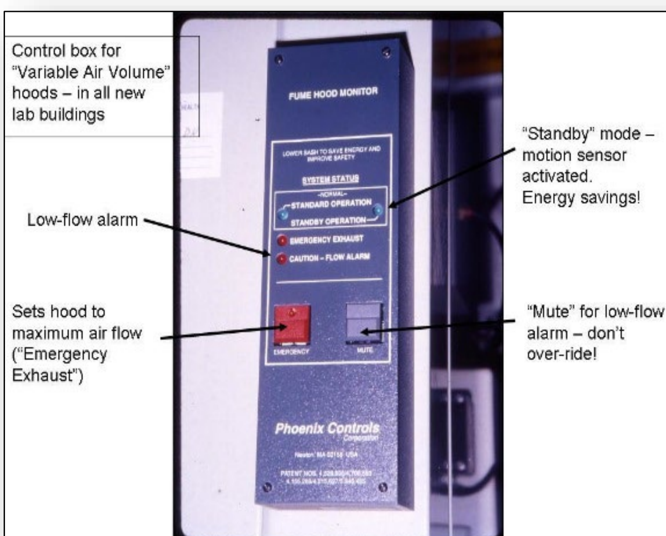
There are two categories of chemical fume hood on campus: Constant Air Volume (CAV) and Variable Air Volume (VAV). As the name suggests, Constant Air volume (CAV) hoods always remove the same volume of air per unit time from the room, regardless of sash height. These hoods are calibrated such that the Cal/OSHA required working airflow rate of at least 100 linear feet per minute (fpm) averaged over the opening of the hood is achieved when the movable sash is placed at the marked working height of 18 inches. Sash heights greater than 18 inches produce an airflow rate below 100 fpm, which is not suitable for working with hazardous materials. Sash heights greater than 18 inches may be used for installation of equipment and other operations that do not present a chemical exposure hazard. All hoods are required to have at least one type of continuous monitoring device designed to provide the user with current information on the operational status of the fume hood. CAV hoods will have one of the following performance indicators attached to them: magnehelic gauges or electronic flow alarms, shown in figure 3.6. Magnehelic gauges do not provide an audible alarm when the flow rate of the fume hood has deviated from normal. Rather the user must visually check the gauge for deviations. The electronic flow alarms have an audible alarm that alerts the user of hood malfunction.

Figure 3.6

Magnehelic Gauge: Visual/non-audible | **Electronic flow alarm: Visual and audible**

Variable Air Volume (VAV) hoods are equipped with valves and sash height sensors that allow the hood to achieve 100 fpm at any sash height. However, this is an energy saving feature, and the working sash height is still 18 inches. The presence of the sash created a barrier between the worker and the materials in the hood and therefore protects from splash hazards, etc. For VAV hoods, the required monitoring device consists of a hood monitor box as shown in figure 3.7. In addition to providing an audible alarm indicating inappropriate airflow, it also has indicators for when the hood is in 'standby mode' (no worker present, airflow at 60 fpm) vs. standard mode (worker presence detected by motion detector, airflow at 100 fpm average). These hoods also have an 'emergency exhaust' button which ramps the airflow up to maximum. This setting should only be used during emergencies, as it can disrupt and knock over items in the hood.

Figure 3.7



Publication date January 2023

Additional fume hood types include those designed for use with strong corrosives like hydrofluoric acid (acid hoods), and the potentially explosive perchloric acid (Perchloric acid wash-down hoods). If you are using either of these materials, please contact EH&S for a hazard assessment and safety equipment evaluation.

Fume hoods should be used when working with all hazardous substances. In addition, a fume hood or other suitable containment device **must** be used for all work with Particularly Hazardous Substances (PHS). A properly operating and correctly used fume hood can reduce or eliminate inhalation hazards present when working with volatile liquids, dusts and mists. When hazardous materials are present in a hood, but it is not under active use (such as during unattended operations), the movable sash should be completely closed. Fume hoods are not designed to be used as storage areas, and are not to be used as such unless no other operations are conducted in that hood.

General Rules for Fume Hood Use

1. **Fume hoods should not be used unless they have a certification sticker that is dated within the past year.**
2. **Before beginning work, check the hood monitoring device to confirm proper hood function.**
3. **Always keep hazardous materials >6 inches behind the plane of the sash.**
4. **Work with the movable sash at the marked 18 inch working height.**
5. **For walk-in style hoods, where the hood and sashes extend to the floor of the lab, keep the sash opening as small as possible as a large opening can create difficulty in maintaining airflow and allows for turbulence.**
6. **Do not clutter your hood, as this blocks airflow and provides fuel for any potential lab fire. Only materials actively in use should be present.**
7. **Do not modify hood, duct work, or the exhaust system without prior EH&S approval.**
8. **Do not use hood as a storage area for chemicals or large equipment unless the hood is dedicated to one of these functions.**
9. **Close the sash when the hood is not in active use.**

Fume hoods are evaluated for operation and certified by EH&S on an annual basis. Hoods certified for use with certain regulated carcinogens are evaluated semi-annually. These evaluations verify the proper fume hood air flow velocity (100 fpm) to ensure that the unit will operate as designed. Data on fume hood monitoring is maintained by EH&S. Additionally, they must be inspected upon installation, renovation, a problem is reported, or a change has been made to the operating characteristics of the hood. A fume hood must have a current calibration sticker and a marker indicated the sash height to be used when working with hazardous materials (18 inches). If these labels are missing, do not use the hood, and contact EH&S at 805-893-3194 for an immediate fume hood evaluation. Routine maintenance and repair of fume hoods are conducted by Facilities Management. If any problems with the fume hood occurs, or if the audible alarm is going off, contact Facilities Management at 805-893-8300.

Somewhat related to chemical fume hoods are laminar flow hoods and biosafety cabinets. The key differences are summarized in figure 3.8. Laminar flow hoods generally do not offer personnel protection, and therefore are not considered engineering controls. The exception is exhausted laminar flow hoods, which are connected to building exhaust and do not recycle air back into the laboratory. Biosafety cabinets do offer personnel protection, as well as environmental protection from biohazardous material. Note that many biosafety cabinets recirculate air back into the laboratory after it passes through a high efficiency HEPA filter. These filters do not remove chemical contamination. Therefore, **never use volatile hazardous chemicals in a recirculating biosafety cabinet**. For biosafety cabinets that are exhausted to the outside of the building, keep the use of hazardous chemicals to a minimum, as these cabinets are not designed with chemical fume protection as a primary consideration. Further training on biosafety cabinets is provided in the mandatory BSL-2 and Blood Borne Pathogen training, as well as hands-on by the PI or delegate.

Figure 3.8

Protection	Biosafety Cabinet Class II type A2	Chemical Fume Hood	Laminar Flow Hood
Personnel	Yes	Yes	No*
Product	Yes	No	Yes
Environment	Yes	No	No

*Unless hard-ducted to building exhaust

Glove Boxes

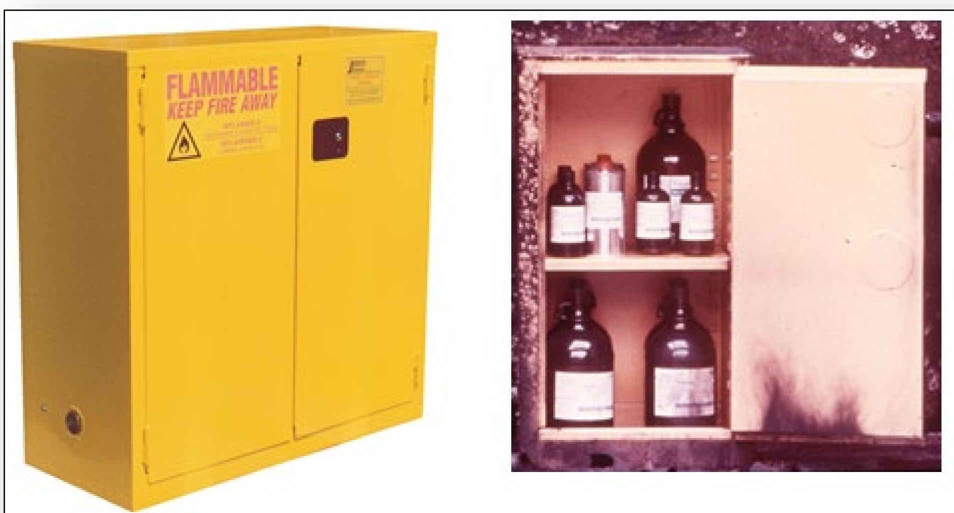
In addition to fume hoods, some laboratories use glove boxes, also known as dry boxes, for working with reactive chemicals under an inert atmosphere, working with very toxic substances, or for creating a stable, draft-free system for weighing hazardous or reactive materials (Figure 3.9). These units require specialized, hands-on training on proper use, and this training must be documented.

Figure 3.9 Glove Box

Hazardous Materials Storage Equipment

Beyond the handling of hazardous materials, engineering controls also come into play in the storage of these materials. Due to these strict mandates regarding flammable chemical storage outlined in the California Fire Code, one of the most important storage devices is the flammable storage cabinet (figure 3.10). Others include 'de-sparked' refrigerators and freezers, and compressed gas cylinder mounts. These are discussed at length later in this document in the section Chemical Inventory, Storage and Transport.

Figure 3.10: Flammable Storage Cabinets



Administrative Controls

Administrative controls consist of policies, procedures and trainings designed to reduce or prevent exposures to laboratory hazards. These controls require the user to exhibit strong situational awareness and act prudently while in the laboratory. This behavioral element is the reason administrative controls are placed one tier below engineering controls in the hierarchy of controls.

General Laboratory Practices

PI's/Laboratory Supervisors are strongly encouraged to establish and document clear rules for the following activities:

- *Working alone in the laboratory*. A laboratory-specific Standard Operating Procedure (SOP) that defines those laboratory activities that may not be undertaken while alone in the laboratory should be included with other laboratory SOP's.

- *Unattended laboratory operations*: Some requirements might include a posted description of the operation, the use of a thermocouple and over-temperature shutoff, and the use of flow sensors for cooling water.

- *Modifying a laboratory specific SOP* in such a manner that the overall hazard is increased substantially. A prime example of this is the scale-up of a chemical reaction. It is strongly recommended that the PI/Laboratory Supervisor establish upper limits for the quantities of materials used in the cases of potentially explosive, extremely reactive and acutely toxic chemicals, and require prior approval for work when these limits are exceeded.

Standard operating Procedures

To supplement the general guidance regarding laboratory work with chemicals that is contained in this Chemical Hygiene Plan, PI's/Laboratory Supervisors are required to develop and implement laboratory-specific SOP's for hazardous chemicals that are used in their laboratories per Cal/OSHA regulation 8 CCR §5191 (e)(3)(A). The development and implementation of SOP's is a core component of promoting a strong safety culture in the laboratory and helps ensure a safe work environment. These SOP's should be written by laboratory personnel who are most knowledgeable and involved with the chemical/operation involved. Completed SOP's must be approved and signed by the PI/Laboratory Supervisor. Factors to consider when writing an SOP, in addition to the hazards inherent to the material, include frequency of use, ranges in scale, temperature, and pressure, and *circumstances requiring prior approval by the PI/Laboratory Supervisor*. To assist researchers with this effort, an SOP template library has been created that contains templates that cover all hazard classes of chemicals, plus a number of chemical specific SOP's. EH&S is available to assist researchers in filling out the required fields and thereby creating a completed SOP, and in developing an SOP from scratch if a suitable template is not available.

SOP's shall be reviewed, and revised as needed, when one of the following criteria is met:

- Hazard level is altered due to changes in experimental conditions such as temperature, pressure, or scale.

- Equipment changes.

- An unexpected outcome occurs, resulting in a reassessment of the hazard/risk profile.

SOPs should be maintained along with this Chemical Hygiene Plan in hardcopy and/or electronic format and be readily available to laboratory personnel. All lab members must read and sign the Chemical Hygiene Plan and their research group's associated SOP's before entering the laboratory.

Particularly Hazardous Substances

Additional administrative controls must be implemented in order to work safely with PHS's. These include:

- Establishment of designated areas.
  - Can be as small as a single fume hood, but often encompasses the entire lab.
  - Only personnel trained on PHS use have access to the designated area.
  - The designated area should be designed in a way that will contain spills to that area.

- Containment devices (e.g. fume hoods) MUST be used at all times while handling PHS, to ensure there is no worker exposure.

- Segregated and clearly labeled storage areas exclusively for PHS must be provided.

- Procedures for contaminated waste disposal.

- Decontamination procedures must be followed: Work surfaces should be decontaminated upon completion of work. Soap and water are effective for removing most chemical residues, however some chemicals require the use of specific agents (e.g. hypophosphorous acid for inactivation of ethidium bromide).

A searchable list of Particularly Hazardous Substances has been generated by EH&S and is updated annually.

Laboratory Hazard Assessments

As mentioned previously, each PI/Laboratory Supervisor with assigned laboratory space is required to create a hazard assessment for their laboratory. The online ASSESSMENT tool is used to generate and document this assessment, as well as to share this assessment with all group members. In addition to being an administrative control, at UC Santa Barbara it has the additional role of determining what forms of personal protective equipment are necessary to protect the workers from the hazards identified.

Personal Protective Equipment and Appropriate Laboratory Attire

Personal Protective Equipment (PPE) serves as a researcher's last line of defense against chemical exposures and is required by everyone entering a laboratory containing hazardous chemicals. Specific requirements for PPE use and proper laboratory attire are outlined in the UC Personal Protective Equipment Policy. These requirements include, but are not limited to:

- Full length pants and close-toed shoes, or their equivalent.
- Protective gloves, laboratory coats, and eye protection when working with, or adjacent to, hazardous chemicals.
- Flame resistant laboratory coats when working with high hazard materials, pyrophorics, and flammables.

The goal of PPE is to reduce the risk associated with handling hazardous materials and conducting hazardous operations. In some cases, PPE beyond that described above will be required. For example, in cases of high splash hazard, chemical safety goggles may be required in the place of safety glasses, as the goggles form a seal around the face which isolates the eyes more completely from the hazard.

Note that prescription street glasses are not adequate eye protection in the laboratory! The lack of side shields and impact resistant lenses leaves the workers eyes exposed to hazards and susceptible to injury. Safety glasses must have these features and possess the ANSI Z87.1 certification stamp on the lenses or frames to be considered protective eyewear. Wearers of prescription glasses can either purchase prescription safety glasses, or wear over-the-glasses safety glasses or goggles.

The specific type of PPE needed for each worker is determined by the laboratory hazard assessment created by the PI/Laboratory Supervisor in the ASSESSMENT tool. Upon logging on, the worker will be directed to read the hazard assessment and watch a brief PPE training video. **A PPE voucher will then be generated by the tool which lists the required PPE for that worker. This voucher can be redeemed for free PPE at the campus PPE distribution center located in the Chemistry Building (557) room 1432**. This process also documents the issuance of the PPE to that individual.

How to Use and Maintain PPE

PPE should be kept clean and stored in an area where it will not be contaminated. PPE should be inspected prior to use to ensure it is in good condition. It should fit properly and be worn properly. If it becomes contaminated or damaged, it should be cleaned or repaired when possible, or discarded and replaced.

Gloves should be used under the specific condition for which they are designed, as no glove is impervious to all chemicals. Single-use disposable gloves protect only from incidental exposure (e.g. a drop of liquid on the glove) and generally only provide protection for a few seconds. Once contaminated, the glove should quickly be removed and disposed of, the hands washed, and a fresh pair of disposable gloves donned. These gloves should not be used for any operation in which immersion or soaking of the glove is expected, such as rinsing glassware with acetone. For these operations, the appropriate thicker, multiple-use glove should be used (butyl gloves for the acetone example given). Glove manufacturers generally provide glove compatibility charts for their products. Some useful examples are:

- Microflex Chemical Resistance Guide
- Cole Parmer Safety Glove Chemical Compatibility Database
- Ansell Guardian Partner Chemical Protection Guide

In cases where spills or splashes of hazardous chemicals on clothing or PPE occur, the clothing/PPE should immediately be removed and placed in a closed container to prevent further release of the chemical. Heavily contaminated clothing/PPE, as well as PPE contaminated with particularly hazardous substances (PHS) should be disposed of as hazardous waste. Non-heavily contaminated laboratory coats should be cleaned and properly laundered. **Coats can be dropped off at any of eight designated laundry locations on campus. The clean coats are returned to the same drop-off location within two weeks.** Under no circumstances should laboratory coats be laundered at home or at commercial laundromats.

Respiratory Protection

Typically, respiratory protection is not needed in a laboratory. Under most circumstances, safe work practices, small scale usage, and engineering controls (fume hoods, biosafety cabinets, and general ventilation) adequately protect laboratory workers from inhalation hazards. Under certain circumstances, however, respiratory protection may be needed.

Per Cal/OSHA regulation 8 CCR §5144 and UCSB Campus Policy, *all UCSB personnel who use respiratory protection equipment including filtering facepiece respirators (dust masks) shall be included in the UCSB Respiratory Protection Program*. The primary objective of the UCSB Respiratory Protection Program is to prevent harmful exposures to hazardous atmospheres through:

- Elimination of hazardous atmospheres wherever possible through the implementation of effective control measures.

- Where adequate control measures are not feasible, the use of respiratory protection to ensure exposures to hazardous atmospheres do not exceed applicable exposure limits.

Respiratory protection must be selected carefully as most respirators only provide protection against certain types of contaminants within specific concentration ranges. The UCSB Respiratory Protection Manual outlines local requirements for respirator use by campus personnel. These requirements include respirator training, fit testing and a medical evaluation.

The Office of Environmental Health and Safety shall act as the sole source for purchasing, fitting and approving the use of all respiratory protection equipment on campus.

Good Laboratory Practices

In order to maintain a safe workplace, certain basic working habits must be exercised. In the laboratory setting these practices and behaviors address the reduction in risks associated with chemicals, equipment, and sources of physical hazards such as electricity, among other things. Some of these habits are described below.

Chemical Handling

- Use only those chemicals for which the available ventilation system is appropriate. If you are unsure, contact EH&S.
- Review all relevant SDS's and SOP's before beginning a novel operation.
- Properly label and store all chemicals. All chemicals not in immediate use should be in their storage area, not on lab benches or fume hoods.
- Dispose of hazardous waste according to UCSB waste disposal procedure. Do not pour hazardous waste down the drain.
- Be prepared for an accident or spill and refer to the emergency response procedures for the specific material. Information on minor spill mitigation can be found in Chapter 4. For larger spills, or if you are not comfortable addressing the spill for any reason, contact EH&S. In the case of personnel exposure to the:
    - EYE: Promptly flush eyes with water for 15 minutes, then seek medical attention. Bring SDS with you to the medical facility.
    - SKIN: Promptly flush the affected areas for 15 minutes and remove any contaminated clothing, then seek medical attention. Bring SDS with you to the medical facility.

Physical Hazard Handling

In addition to chemical hazards, there are a number of physical hazards that are common in the laboratory setting. These include: pressure and vacuum, sharps, electricity, noise, vibration, temperature extremes, and kinetic energy. Some good practices relating to these physical hazards are:

- Store laboratory glassware with care. Inspect all glassware and other equipment before use; do not use damaged items.

- Use proper syringe techniques. Do not re-sheath used disposable needles.

- Compressed gas cylinders: inspect for damage/corrosion on a regular basis. Use a pressure regulator that is compatible with the bas being used. Check plumbing for leaks. Be aware of the possibility of an oxygen deficient atmosphere being created if the full contents of the cylinder are released rapidly, as upon rupture of the cylinder. Carbon monoxide detectors are easy to purchase and relatively inexpensive. When using carbon monoxide, place a CO detector near plumbing joints or other areas where a leak might occur. Contact EH&S to assess the need for oxygen or other gas monitors.

- Cryogens (Liquid nitrogen and helium, dry ice): Store and transfer only in approved storage vessels. Wear cryogenic gloves when handling. A face shield may be required if there is a significant splash hazard. Be aware of the possibility of an oxygen deficient atmosphere upon the evaporation of the cryogen. Contact EH&S to assess the need for oxygen or other gas monitors.

- Shielding: In situations where explosion (high pressure or high reactivity) or implosion (vacuum) are a possibility, use appropriate shielding to protect from flying fragments and other material. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them to contain chemicals and fragments should implosion occur.

- Electrical Hazards: Do not overload circuits. Do not 'daisy chain' extension cords or power strips. Examine wires for fraying. Do not use extension cords as permanent wiring. Contact Facilities if additional electrical outlets are needed.

- Noise: Loud workspaces are assessed by EH&S, and hearing protection is provided as necessary.

General Laboratory Operations

- Good housekeeping is key to a safe laboratory. Some good practices include:
  - Keeping work areas, especially fume hoods, clean and uncluttered.
  - Preventing the accumulation of dirty glassware, unneeded samples, and trash.

- Keeping aisles and areas around safety shower/eyewash units clear to allow unobstructed exit and easy access to safety equipment in an emergency.
  - Practicing good refrigerator/freezer management by preventing overcrowding, using secondary containment, and completing periodic defrosting procedures.

- Prudent laboratory behavior is also important. Examples include:
  - Do not engage in distracting behavior such as practical jokes in the laboratory, as this can distract or startle other workers.
  - Wash your hands often, and again before leaving the laboratory.
  - Avoid working alone in the laboratory. If work must be conducted alone, restrict this work to that which does not involve significant chemical or physical hazards.
  - Do not bring or consume food/drink in any areas where hazardous materials are stored and handled.
  - Do not handle personal mobile devices while wearing gloves. Do not set a mobile device down on any surface in the lab which may be contaminated with hazardous chemicals.

- Seek information and advice about hazards, plan appropriate protective procedures, and plan positioning of equipment before beginning any new operation.

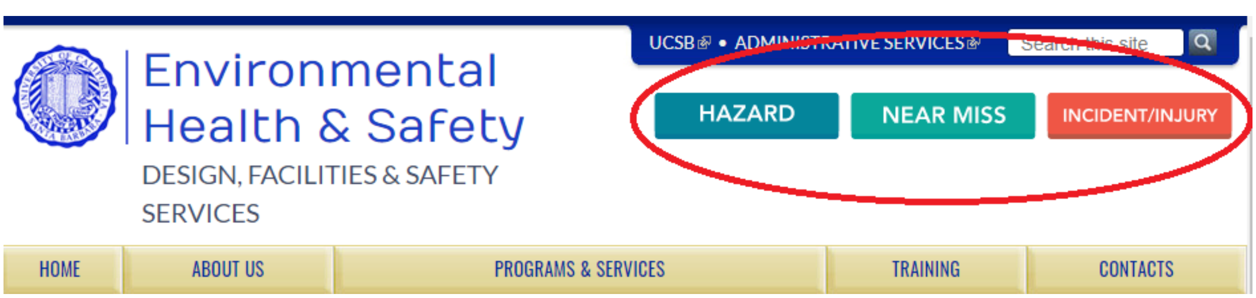
- Be alert to unsafe conditions and ensure that they are corrected when detected.

- If minors are in the laboratory, be sure to follow the UC Policy on Minors in Laboratories and Shops.

- For unattended laboratory operations, ensure that the operation has been approved by the PI/Laboratory Supervisor, the lab or fume hood door has signage in place describing the operation and associated hazards, the lights are left on, and make provisions for the loss of utility service (electricity, flowing water).

- Do not disturb equipment in use or any other laboratory operation without the consent of the user.

- Report all accidents, injuries and near-misses to the PI/Laboratory Supervisor and to EH&S. We cannot learn from these incidents if they are not reported.



- Report all fires to EH&S, and the discharge of any fire extinguisher to Facilities Management at 805.893.8300

Chemical Inventory, Storage, and Transport

Chemical Inventory

An accurate chemical inventory is a necessary part of a healthy chemical hygiene program. Certain minimum requirements for the quality and quantity of chemical inventory data are set by a variety of regulatory agencies. These are:

Local regulations (Santa Barbara County Environmental Health Services)

- Hazardous Materials Business Plan: The County requires businesses to provide information about their bulk hazardous materials, including location, physical state, container type, amount present and maximum amount stored on site during the year. The County uses the information for emergency response planning. For UCSB laboratories and shops to be in compliance they must report any hazardous materials to EH&S which at any one time during the year will be stored in quantities greater than:
    - 500 pounds of a solid.
    - 55 gallons of a liquid.
    - 200 cubic feet of a compressed gas, excluding inert gases, when the volume is calculated at standard temperature and pressure (STP).

- California Accidental Release Prevention Program (CalARP): The purpose of the CalARP program is to prevent accidental release of substances that can cause serious harm to the public and the environment. As such, businesses that handle more than a threshold quantity of a regulated substance are required to report this to the County, and to develop a Risk Management Plan (RMP).

State Regulations

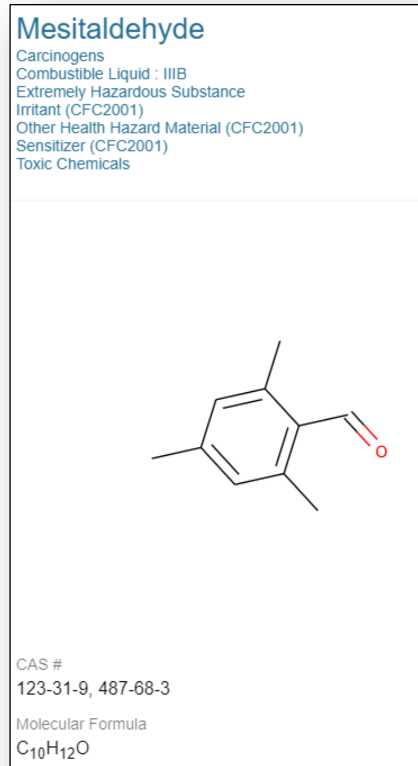
- The California Fire Code (CFC): Title 24 of the California Fire Code defines Maximum Allowable Quantities (MAQ) for certain classes of chemicals, including flammables, oxidizers, pyrophoric/water reactive materials and highly toxic materials. The MAQ's vary depending on building construction and floor above or below ground, and therefore both quantities and location data must be collected for these materials.

- Regulated Carcinogens (Cal/OSHA): These chemicals have very specific handling requirements, including the establishment of designated areas. Therefore, their presence and location on campus must be documented.

Federal Regulations

- [Chemical Facility Anti-Terrorism Standards (CFATS)]: This standard covers a list of chemicals that are of interest to the Department of Homeland Security. The campus is required to report to DHS upon crossing designated threshold amounts of these chemicals. These quantities are calculated for the campus as a whole.

To obtain the data required to comply with these mandated programs, EH&S reviews the annual Laboratory Hazardous Materials Survey with each PI/Laboratory Supervisor during the annual laboratory safety review. All of the required data as described above is compiled via these survey forms, and entered into UC Chemicals, a web-based chemical inventory database.

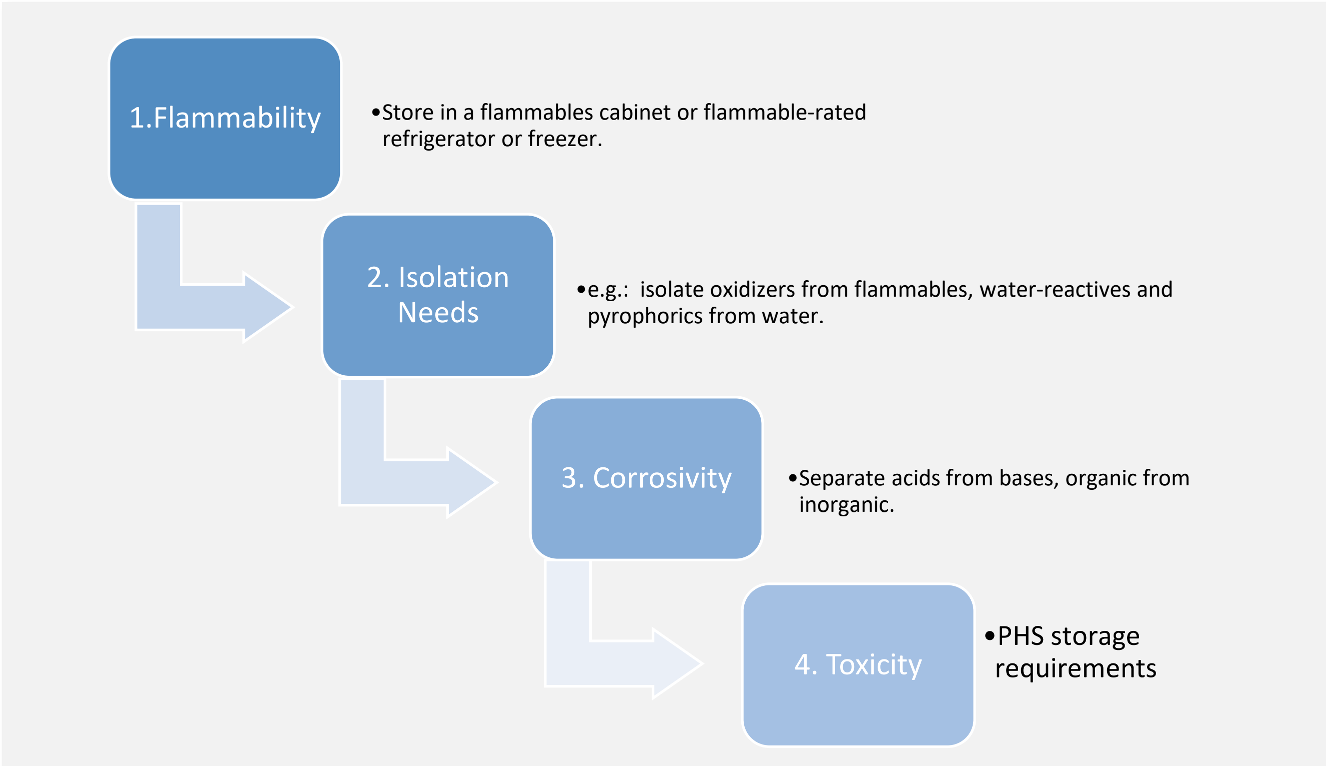


UC Chemicals can also be used directly by the research groups to manage their entire chemical inventory. This is best practice, and encouraged by UC Santa Barbara. Having a complete real-time inventory of all the chemicals in a laboratory, as opposed to just the chemicals required by the above regulations, has a number of benefits. First, it gives the researchers a high-resolution knowledge of all of the chemical hazards present in the laboratory. Second, it aids in the financial and time management of laboratory activities by reducing duplicate ordering, and avoiding delays caused by awaiting the delivery of a chemical reagent that is actually already present in the laboratory. Finally, it helps reduce diversion of chemicals (acquisition for illegitimate or illegal purposes).

Chemical Storage

It is important to establish and follow safe chemical storage and segregation procedures in the laboratory. Storage guidelines for flammable, oxidizing, corrosive, water reactive, explosive and acutely toxic materials are described in the following sections. The specific SDS should always be consulted when doubts arise concerning chemical properties, compatibilities, associated hazards, and storage recommendations. All storage procedures must comply with Cal/OSHA, Fire Code and building code regulations. Figure 3.11 shows the properties to be taken into consideration when developing a storage plan, in order of priority.

Figure 3.11



General Recommendations

Each chemical in the laboratory should be stored in a specific location and returned there after each use. Acceptable chemical storage locations may include corrosive cabinets, flammables cabinets, laboratory shelves, or appropriate refrigerators and freezers. Chemicals should not be routinely stored on laboratory benchtops or on the floor. Fume hoods should not be used as general storage areas for chemicals, as this seriously impairs the ventilating capacity of the hood (Figure 3.12)

Figure 3.12

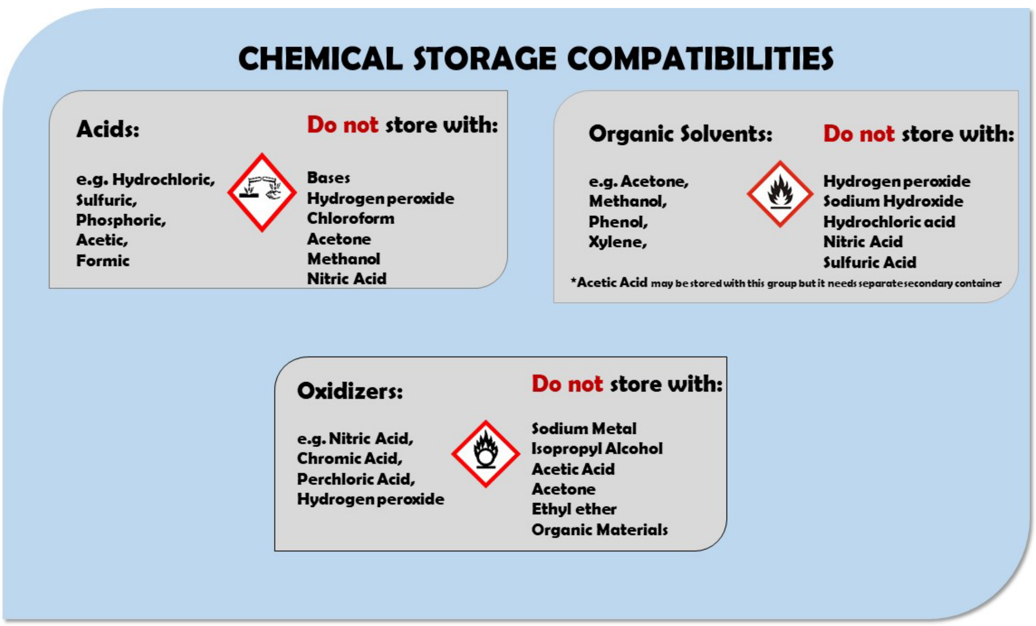
To avoid overcrowding and unnecessary risk, chemicals should be reviewed periodically, and compromised items removed as chemical waste. Some indications for disposal include:

- Cloudiness in liquids
- Color change
- Evidence of liquids in solid material, or solids in liquid material
- 'Puddling' of material around outside of containers
- Obvious deterioration of containers

Laboratory shelves should have a raised lip or railing along the outer edge to prevent containers from falling. Hazardous liquids or corrosive chemicals should not be stored on shelves above eye-level, and chemicals that are corrosive or highly toxic should be stored in secondary containment. Chemicals must be stored at an appropriate temperature and humidity level and should never be stored in direct sunlight or near heat sources, such as laboratory ovens and furnaces.

Incompatible materials should be stored in separate cabinets, whenever possible. If these chemicals must be stored in one cabinet due to space limitations, adequate segregation and secondary containment must be ensured to eliminate the possibility of mixing. Figure 3.13 shows some common chemicals and their storage compatibilities. More detailed information can be found is in Prudent Practices Chapter 5, Section 5.E.2. and Table 5.1. All stored containers and research samples must be appropriately labeled and tightly capped to prevent vapor interactions and to alleviate nuisance odors. Storing chemicals in flasks with cork, rubber or glass stoppers should be avoided due to the potential for leakage.

Figure 3.13



Laboratory refrigerators and freezers must be labeled as "No Food or Drink". Freezers should be defrosted periodically so that chemicals do not become trapped in ice formations.

Flammable and Combustible Liquids

The California Fire Code addresses how much total volume of flammable materials can be stored in a room, floor, or building as a whole. As such, large quantities of flammable or combustible materials should not be stored in the laboratory. No more than **10 gallons** of flammable or combustible liquids, including hazardous waste, are allowed to be kept outside of a flammable storage cabinet, safety can, or approved refrigerator/freezer. The maximum total quantity of NFPA Class 1A flammable liquids within a safety cabinet must not exceed **60 gallons**. These are materials with a flashpoint below 73 °F

(22.8 °C) and boiling points below 100 °F (37.8 °C) such as pentane, diethyl ether, etc. The total volume within a cabinet must not exceed **120 gallons** per cabinet.

Figure 3.14

For flammable materials that require low temperature storage, specialized refrigerators or freezers are used. These 'de-sparked' or 'explosion proof' units are specially designed so that no potential source of ignition is present inside the unit (lightbulbs, switches, thermostat knobs, etc.). This is necessary due to the very low flashpoint and high volatility of many flammable liquids. Build-up of fumes inside the unventilated unit, followed by a spark caused by the lightbulb or the compressor turning on is a known cause of multiple laboratory explosions. As standard refrigerators and freezers are also present in the laboratory for non-flammable storage, it is important to be able to distinguish between the two. Figure 3.14 shows the standard warning label placed on all refrigerators that are not suitable for flammable storage. Other identifiers include the presence of lightbulbs, switches and other controls inside the unit. If you are uncertain whether or not a unit is safe for flammable storage, contact EH&S.

Always segregate flammable or combustible liquids from oxidizing acids and oxidizers (e.g. nitric acid). Flammable liquids or gases must never be stored in domestic-type refrigerators/freezers. Flammable or combustible liquids must not be stored on the floor or in any exit access. Handle them only in areas free of ignition sources, and in a fume hood whenever possible. Only the amount of material required for the procedure should be stored in the work area.

Static electricity is a concern when handling flammable and combustible liquids, as a small spark is often sufficient to act as an ignition source. Metal drums must be grounded and bonded during the dispensing process, and a metal pump should be used. Avoid pouring directly from metal drums.

Pyrophoric and Water Reactive Materials

Because pyrophoric substances can spontaneously ignite on contact with air and/or water, they must be handled under an inert atmosphere and in such a way that rigorously excludes air and moisture. Some pyrophoric materials are also toxic and many are dissolved or immersed in a flammable solvent. Other common hazards include corrosivity, teratogenicity, or peroxide formation. **Before working with pyrophoric materials, individuals must demonstrate knowledge of the appropriate methods to handle, transfer, and quench the material being used.**

Only minimal amounts of reactive chemicals should be used in experiments or stored in the laboratory. These chemicals must be stored as recommended in the SDS. Suitable storage locations may include inert gas-filled desiccators, glove boxes, or a flammable substance approved refrigerator/freezer. Reactive material containers must be clearly labeled with the correct chemical name, in English, along with a hazard warning. If pyrophoric or water reactive reagents are received in a specially designed shipping, storage or dispensing container (e.g. Aldrich Sure/Seal™ packaging system) ensure that the integrity of that container is maintained. Ensure that sufficient protective solvent, oil, kerosene, or inert gas remains in the container. Never store reactive chemicals with flammable materials or in a flammable liquid storage cabinet.

Storage of pyrophoric gases is described in the California Fire Code, Chapter 41, and requires gas cabinets with remote sensors and fire suppression. Gas flow, purge and exhaust systems must also have redundant controls to prevent the pyrophoric gas from igniting or exploding. Emergency back-up power should be provided for all electrical controls, alarms and safeguards associated with the pyrophoric gas storage and process systems. As such, *purchase of pyrophoric gases is restricted and requires EH&S approval via the Gateway purchasing system to ensure the necessary infrastructure is in place before the arrival of the material*.

Oxidizers

Oxidizers such as hydrogen peroxide, halogen gas, potassium permanganate, sodium nitrate, nitric acid, perchloric acid, etc. should be stored in a cool, dry place and kept away from flammable and combustible materials including wood and paper, Styrofoam, plastics, flammable organic chemicals, and away from reducing agents such as zinc, alkali metals, metal hydrides and formic acid.

Vented caps must be used on containers for waste streams of oxidizing inorganic acids or pressure-generating materials (nitric acid, aqua regia piranha etch). These requirements are outlined in the SOP templates for these materials

Peroxide Forming Chemicals (Time-Sensitive Materials)

Peroxide forming chemicals (ethereal solvents, cyclohexene, etc.) should be stored in airtight containers in a dark, cool and dry place and must be segregated from other classes of chemicals that could create a serious hazard to life or property should an accident occur (e.g. acids, bases, oxidizers). All containers should be labeled with the date received and the date opened. This information, along with the chemical identity, should face forward to minimize handling during inspection. Minimize the quantity of peroxide forming chemicals stored in the laboratory and dispose of them before peroxide formation occurs. Refer to the 'Hazard Classes – Peroxide Forming Chemicals' section of this document for information on expiration times for the different classes of peroxide formers. Carefully review all cautionary materials supplied by the manufacturer prior to use. Avoid evaporation or distillation, as distillation defeats the stabilizer added to the solvents. Ensure that containers are tightly sealed to avoid evaporation and that they are free of exterior contamination or crystallization.

Do not handle a container of peroxide forming chemicals if:

- If it greater than five years old, or of undetermined age.
- Crystallization is present in or on the exterior of the container.
- An oily second layer is present in the container.

In this situation, immediately restrict access to the area and contact EH&S.

Potentially Explosive Chemicals

Potentially explosive chemicals such as dibenzoyl peroxide, trinitrobenzene, picric acid and salts, and perchloric acid and salts, should be stored at the manufacturers' recommended temperature in an explosion-proof refrigerator, freezer or cabinet. They should be kept away from heat, light, friction, impact, and any other potential initiating mechanisms. They should be stored away from flammable and combustible materials. Picric acid and perchloric acid should be kept away from metals and metal salts, with which they can react for form highly explosive products. Picric acid becomes most explosive when dry, and therefore must contain at least 10% water for inhibition. If a bottle of Picric acid of unknown age or condition is found in the lab, isolate the area and contact EH&S. Perchloric acid should be stored by itself, away from all other chemicals.

Corrosives

Store corrosive chemicals (acids, bases) below eye level and in secondary containers that are large enough to contain either 10% of the total volume of liquid stored, or the volume of the largest container, whichever is greater. Acids must be segregated from bases and from active metals such as sodium, potassium and magnesium, as well as from chemicals which could generate toxic gases upon contact such as sodium cyanide and iron sulfide. Additionally, mineral acids must be kept away from organic acids, and oxidizing acids must be segregated from flammable and combustible substances.

Compressed Gases

Compressed gas cylinders must be mounted to a bracket or rack that has been bolted to a structural component of the building, or to casework that is itself bolted to the structure. The cylinder must be held in place by two chains, at 1/3 and at 2/3 height. The safety cap must be in place unless the gas is currently in use (regulator attached). All connections must be inspected frequently. Never used a compressed gas cylinder without a regulator.). For toxic gases, a gas cabinet provides a storage area that is ventilated to the exterior of the building in case of a leak or rupture (Figure 3.15).

Figure 3.15: Gas Cylinder Storage

Even an inert, non-toxic gas like nitrogen poses an asphyxiation risk if the pressure in a nitrogen tank is released suddenly enough to overwhelm room ventilation when present in confined spaces (an elevator or closet) or in poorly ventilated areas (a cold room). Contact EH&S prior to locating cryogenic liquids in these areas to assess if oxygen monitoring is necessary.

For toxic gases, a gas cabinet provides a storage area that is ventilated to the exterior of the building in case of a leak or rupture. Flammable gas cylinders must use only flame-resistant gas lines and hoses, and must have all connections leak-tested. Compressed oxygen gas cylinders must be stored at least 20 feet away from combustible materials and flammable gases, or be separated by a non-combustible partition.

Corrosive gases should be consumed or disposed of within 2 years due to the potential of cylinder failure. This failure can occur via two routes. One is that some acids slowly build up dangerous pressures of hydrogen gas via reaction with the metal cylinder walls resulting in explosion (e.g. HF). The other is the corrosion of the metal components of the cylinder resulting in leaks or frozen valves.

Cryogens

Because cryogenic liquid (e.g. Nitrogen, Argon, Helium, etc.) containers are at low pressure and have protective rings mounted around the regulator, they are not required to be affixed to a permanent fixture such as a wall. However, additional protection considerations should be addressed when storing cryogenic liquids in a laboratory. The primary risk to laboratory personnel from cryogenic liquids is skin or eye damage caused by contact with the material. Always wear eye/face protection and thermally insulated gloves while handling these materials. Additionally, all cryogenic liquids have large expansion volumes, typically greater than 500:1 when transitioning from a cryogenic liquid to a gas at standard temperature and pressure. This volumetric increase can create two types of hazard:

- High pressure: Use only specially designed containers, and ensure that pressure relief valves are functional and unobstructed before use.

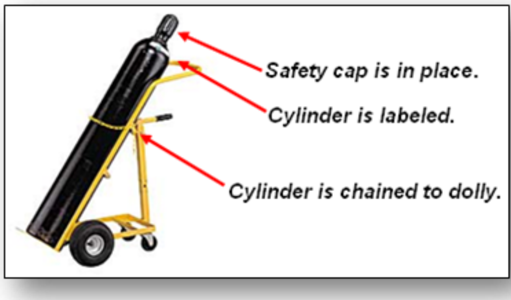
- Oxygen displacement: As is the case for inert compressed gases, while usually non-toxic, there is an asphyxiation risk when cryogenic liquids are present in confined spaces (an elevator or closet) or in poorly ventilated areas (a cold room). Contact EH&S prior to locating cryogenic liquids in these areas to assess if oxygen monitoring is necessary.

Transporting Chemicals

On-Campus Transport of Hazardous Chemicals

Precautions must be taken when transporting substances between laboratories. Chemicals must be transported in break-resistant secondary containers such as commercially available bottle carries that include a carrying handle, or plastic tubs on a sturdy cart with a railing. Chemicals must not be left unattended. Ensure that your destination is accessible before departing.

Figure 3.16



When transporting compressed gas cylinders (Figure 3.16):

- Disconnect regulators and other apparatus prior to transport.
- Always replace the valve safety cap before transporting cylinders.
- Cylinders must always be transported using a hand truck or cart designed for that purpose.
- Transport cylinders upright.

When transporting compressed gases *on elevators*, use service or freight elevators when available. In addition, when transporting compressed gases by elevator:

- Post a sign reading “DO NOT ENTER – GAS TRANSPORT” to exclude passengers. Send the elevator to the desired floor, but do not enter the elevator yourself.
- When possible, have someone send the elevator up while another person waits on the receiving floor to take the cylinder out of the elevator. If this is not possible, another plan should be devised to ensure that the cylinder is taken out of the elevator once it reaches the desired floor.

Off-Campus Transport or Shipment of Hazardous Chemicals

The transport of hazardous chemicals and compressed gases over public roads or by air is strictly governed by international, federal, and state regulatory agencies, including the U.S. Department of Transportation (DOT) and the International Air Transport Association (IATA). Any person who prepares and/or ships these types of materials must ensure compliance with pertinent regulations regarding training, quantity, packaging, and labeling. *Without proper training, it is illegal to ship hazardous materials.* Those who violate the hazardous materials shipment regulations are subject to criminal investigation and penalties. UC Santa Barbara personnel who sign hazardous materials manifests, shipping papers, or those who package hazardous materials for shipment must be trained and certified by EH&S.

Individuals who wish to transport hazardous chemicals or compressed gases off-campus using a UC Santa Barbara or personal vehicle should contact EH&S to ensure safety and compliance. Some information can be found here.

Chemical Security

Access to hazardous chemicals should be restricted at all times. At a minimum, these materials must be stored in laboratories or storerooms that are kept locked when laboratory personnel are not present. Other requirements come into play for chemicals that are of interest to the Drug Enforcement Agency (controlled substances), the Federal Bureau of Investigations (weapons of mass destruction), and the Department of Homeland Security (Chemical Facility Anti-Terrorism Standard 'CFATS' Chemicals of Interest). These requirements are elucidated at the time of acquisition of these materials.

Per Prudent Practices, areas of concern related to laboratory security include:

- Theft or diversion of chemicals, biologicals, and radioactive or proprietary materials.
- Theft or diversion of mission-critical or high-value equipment.
- Threats from activist groups.
- Intentional release of, or exposure to, hazardous materials.
- Sabotage or vandalism of chemicals or high-value equipment.
- Loss or release of sensitive information.
- Rogue work or unauthorized laboratory experimentation.

It is each laboratory's responsibility to report any theft of chemicals from their laboratories to EH&S. Reporting to one or more of the above-listed agencies may be required depending on the nature of the material stolen.

Chemical Exposures: Limits, Assessments, and Medical Evaluations

Regulatory Overview

Under Article 107 of Title 8, Cal/OSHA requires that all employers, "*measure an employee's exposure to any substance regulated by a standard which requires monitoring if there is reason to believe that exposure levels for that substance exceed the action level (or in the absence of an action level, the exposure limit)."* Repeated monitoring may be required if initial monitoring identifies exposures over the action level or the permissible exposure limit.

- *Permissible Exposure Limits (PEL)* are the maximum permitted 8 hour Time Weighted Average (TWA) exposure concentration of an airborne contaminant without the use of respiratory protection.

- *Short-Term Exposure Limits (STEL)* are the maximum permitted 15 minute TWA exposure concentration without the use of respiratory protection.

- *Ceiling Limits (C)* are the exposure concentration of an airborne contaminant that may not be exceeded at any time.

- *Action levels (AL)* are exposure levels at which exposure initiates certain required activities such as exposure monitoring and medical surveillance, and are generally a fraction of the permissible exposure limit.

Cal/OSHA has listed established PELs, STELs and Ceiling limits for chemical contaminants identified in 8 CCR §5155 (Airborne Contaminants) Table AC-1. Cal/OSHA requires that exposures exceeding these levels be controlled in order to prevent harmful health effects. Beyond this list, Cal/OSHA has promulgated specific standards covering several regulated carcinogens, which may include and Action Level (AL), triggering medical surveillance requirements or the imposition of a specific Excursion Limit (such as for asbestos) with a unique measurement of the duration of an exposure.

Exposure Assessments

All UC Santa Barbara employees require protection from exposure to hazardous chemicals above the PELs, STELs and Ceiling limits. In the absence of sufficient engineering controls, an exposure assessment must be conducted in order to ensure exposure limits are not being exceeded. Cal/OSHA requires the person supervising, directing or evaluating the exposure assessment be competent in the practice of industrial hygiene. Thus, exposure assessments should be performed only by representatives of EH&S.

EH&S utilizes various methods when assessing exposure to hazardous chemicals. These include employee interviews, visual observation of chemical use, evaluation of engineering controls, use of direct reading instrumentation, and the collection of analytical samples from the employee's breathing zone. The assessment will then look at various ways to minimize an exposure, using a combination of elimination, substitution, engineering controls, administrative controls, and person protective equipment, listed in order of priority. Personal exposure assessments may be performed under situations including the following:

1. As determined based on EH&S review of chemical inventories, SOP's, Laboratory Hazard Assessment Tool (LHAT) assessments types of engineering controls present, and/or laboratory safety review outcomes.

2. Concern expressed by a chemical user as to whether exposure is minimized or eliminated through the use of engineering controls or administrative practices. The user should then inform his or her PI/Laboratory Supervisor, who will in turn contact EH&S.

3. A regulatory requirement exists to perform an initial and if warranted periodic monitoring.

If you are concerned about exposures to chemicals or other hazards in your laboratory, please contact your EH&S laboratory safety representative to schedule an exposure assessment. ***In the event of any serious injury or exposure, including chemical splash involving skin or eye contact, call 911 to obtain medical treatment immediately.*** Do not wait for an exposure assessment to be performed before seeking medical care.

Exposure Assessment Protocol

The EH&S Industrial Hygiene Program conducts exposure assessments for members of the campus community. Per Cal/OSHA 8 CCR § 340.1, employees have a right to observe testing, sampling, monitoring or measuring of employee exposure. They are also allowed access to the records and reports related to the exposure assessment. Exposure assessments may be performed for hazardous chemicals, as well as for physical hazards including noise and heat stress, to determine if exposures are within PELs or other appropriate exposure limits. General protocol for conducting an exposure assessment may include any of the following:

1. Employee interviews.

2. Visual observation of chemical usage and/or laboratory operations.

3. Evaluation of simultaneous exposure to multiple chemicals.

4. Evaluation of potential for absorption through the skin, mucus membranes, or eyes.

5. Evaluation of existing engineering controls.

6. Use of direct reading instrumentation.

7. Collection of analytical samples of concentrations of hazardous chemicals taken from the employee's breathing zone, noise dosimetry collected from an employee's shirt collar, or various forms of radiation dosimetry.

If exposure monitoring determines that an employee's exposure is over the Action Level or PEL for a hazard for which Cal/OSHA has developed a specific standard (e.g. lead, methylene chloride), the medical surveillance provisions of that standard shall be followed (see the *Medical Surveillance* section below). If there is no published PEL, STEL or Ceiling limit, EH&S defers to the *Threshold Limit Values (TLV)* established by the American Conference of Governmental Industrial Hygienists (ACGIH), or the *Recommended Exposure Limits (REL)* established by the National Institute of Occupational Safety & Health (NIOSH). It is the responsibility of the PI/Laboratory Supervisor to ensure that nay necessary medical surveillance requirements are met.

Notification of Results

The Industrial Hygiene Program will promptly notify the employee and PI/Laboratory Supervisor of the results of the assessment in writing within 15 days, or less if required by regulation, after the receipt of any exposure monitoring results. The Industrial Hygiene Program will establish and maintain accurate records of any measurements taken to monitor exposures for each employee. Records, including monitoring provided by qualified vendors, will be managed in accordance with Cal/OSHA regulation 8 CCR §3204.

Determination and Implementation of Necessary Controls

When necessary, the results of the assessment will be used by EH&S to determine what control measures are required to reduce the employee's occupational exposure. Particular attention shall be given to the selection of safety control measures for chemicals that are known to be extremely hazardous. Per Cal/OSHA regulation 8 CCR §5141 the control of harmful exposures shall be prevented by implementation of control measures in the following order:

1. Elimination, whenever possible.

2. Substitution, whenever possible.

3. Engineering controls, whenever feasible.

4. Administrative controls, whenever engineering controls are not feasible or do not achieve full compliance, and these administrative controls are practical.

5. Personal Protective Equipment, including respiratory protection
    a. During the time period necessary to install or implement feasible engineering controls.
    b. When engineering controls and administrative controls fail to achieve full compliance.
    c. In emergencies.

Medical Evaluations

All employees, student workers, medical health services volunteers, or laboratory personnel who work with hazardous chemicals shall have an opportunity to receive an employer-provided medical evaluation, including any supplemental examinations that the evaluating physician deems necessary, under the following circumstances:

- Whenever an employee develops signs or symptoms associated with a hazardous chemical to which they may have been exposed at the work area.

- Where personal monitoring indicates exposure to a hazardous chemical is above the Cal/OSHA AL or PEL, or, if these are not established, the TLV or REL as defined in the previous section.

- Whenever an uncontrolled event takes place in the work area such as a spill, leak, explosion, fire, etc., resulting in the likelihood of exposure to a hazardous chemical.

- Upon reasonable request of the employee to discuss medical issues and health concerns regarding work related exposure to hazardous chemicals.

All work-related medical evaluations and examinations will be performed at the Sansum Clinic Occupational Medicine Center by licensed physicians or staff under the supervision of a licensed physician. Evaluations and examinations will be provided without cost to the employee, without loss of pay, and at a reasonable time.

Information to Provide to the Clinician

At the time of the medical evaluation, the following information should be provided by the employee:

1. Employee ID number.

2. Common and/or IUPAC name of the hazardous chemical to which the individual may have been exposed

3. **A copy of the Safety Data Sheet (SDS) of the hazardous chemical in question.**

4. A description of the conditions under which the exposure occurred.

5. Quantitative exposure data, if available (e.g. from exposure monitoring).

6. A description of the signs and symptoms of exposure that the employee is experiencing, if any.

7. A history of exposure, including from previous employment and non-occupational activities.

8. Healthcare providers must be informed of *any* biological materials present in the laboratory.

Physician's Written Opinion

For evaluations or examinations required by Cal/OSHA, the employer shall receive a written opinion from the examining physician which shall include the following:

1. Recommendations for further follow-up.

2. Results of the medical examination and any associated tests, if requested by the employee.

3. Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous chemical found in the workplace.

4. A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

Confidentiality and Individual's Access to Personal Medical Records

All patient medical information is protected by both California and Federal lab, and is considered strictly confidential. Sansum Clinic is prohibited from disclosing any patient medical information that is not directly related to the work-related exposure under evaluation, and will not reveal any diagnosis unrelated to the work-related exposure.

- Any patient information disclosed by Sansum Clinic to the employee's supervisor will be limited to information necessary in assessing an employee's return to work, including recommended restrictions in work activities, if any.

- Any patient information disclosed by Sansum Clinic to EH&S will be limited to information necessary to develop a course of exposure monitoring, or perform hazard assessments and incident investigations, if appropriate.

Sansum Clinic will otherwise disclose patient medical information only as required by California and Federal law, such as for Worker's Compensation Insurance claims**.** *However, each employee has the right to access his/her own personal medical and exposure records*. Sansum Clinic will provide an employee with a copy of his/her medical records upon written request.

Medical Surveillance

Medical surveillance is the process of using medical examinations, questionnaires and/or biological monitoring to determine potential changes in health as a result of exposure to a hazardous chemical or other hazards. Certain Cal/OSHA standards require clinical examination as part of medical surveillance when exposure monitoring exceeds an established Action Level or PEL.

Medical Surveillance is required of employees who are routinely exposed to certain hazards as part of their job description (such as asbestos) and may be offered to other employees based upon quantifiable or measured exposure.

Examples of hazards that are monitored through the medical surveillance program include:

- Asbestos
- Berylium
- Formaldehyde
- Noise (Hearing Conservation Program)
- Radioactive Materials (Bioassay Program)
- Respirator Use

- Lead
- Methylene Chloride
- Other Particularly Hazardous Substances

Hazardous Chemical Waste Management

In California, hazardous waste is regulated by the Department of Toxic Substance Control (DTSC), a division within the California Environmental Protection Agency (Cal/EPA). Federal EPA regulations also govern certain aspects of hazardous waste management, since most of our waste is treated and disposed out of state. These federal regulations are part of the Resource Conservation and Recovery Act (RCRA). Local enforcement is administered by the Santa Barbara County Department of Public Health via the Certified Unified Program Agency (CUPA).

UC Santa Barbara Hazardous Waste Program

The Hazardous Waste Program is responsible for providing cost-effective hazardous waste management in compliance with federal state, and local regulations. It provides waste pickup, emergency spill response and assistance with shipping hazardous materials. Additionally, it is responsible for pollution prevention, regulatory reporting, and maintaining campus emergency response capabilities. Each laboratory user must comply with the UCSB hazardous waste disposal procedures to ensure that all regulatory requirements are being met. Regularly scheduled waste pick-up service is in place for large volume generators in most buildings with wet labs, however, pick-ups are also available upon request in those buildings as well as those without scheduled pick-ups. Laboratory personnel are responsible for identifying waste, labeling it, and storing it properly in the laboratory. Laboratory clean-outs/decommissioning and disposal of high hazard compounds (expired peroxide formers, dried picric acid, abandoned unknown chemicals, etc.) must be scheduled in advance.

Definition of Hazardous Waste

EPA regulations define hazardous waste as substances having one or more of the following characteristics:

- *Corrosive*: pH $\leq$ 2 or $\geq$12.5
- *Ignitable*: Liquids with a flash point below 60 °C or 140 °F.

- *Reactive*: unstable, explosive, reacts violently with air and/or water, or releases a toxic gas when in contact with water.

- *Toxic*: As determined by toxicity testing.

The EPA definition of hazardous waste also extends to the following items:

- Abandoned chemicals.

- Unused or unwanted chemicals.

- Chemicals in compromised containers (ruptured, punctured, corroded, etc.)

- Empty containers that have visible residues.

- Containers with conflicting labeling (dual labeling).

- Unlabeled or unknown chemicals.

Chemicals not in frequent use must be carefully managed to prevent them from being considered a hazardous waste. This is especially true for certain compounds that degrade and destabilize over time and require careful management so that they do not become a safety hazard, as described in the section below entitled 'Waste that Requires Special Handling'.

Extremely Hazardous Waste

Certain compounds meet an additional definition known as 'extremely hazardous waste'. This list of compounds includes carcinogens, pesticides, and reactive compounds, among others. Some examples include cyanides, sodium azide, and hydrofluoric acid. The Federal EPA refers to this waste as 'acutely hazardous waste, but Cal/EPA has published a more detailed list of extremely hazardous waste. Both the state and federal lists are included in the EH&S List of Extremely Hazardous Waste. Note: This list, although having some overlap, should not be confused with the list of Particularly Hazardous Substances previously addressed in this document.

Proper Hazardous Waste Management

Training

All personnel who are responsible for handling, managing or disposing of hazardous waste must complete training. Hazardous Chemical Waste training is a component of the Fundamentals of Laboratory Safety course offered by EH&S both live and online. This satisfies the training requirement.

However, if further training is desired, there is an additional online UCSB Hazardous Waste Generator training available through the learning center as well.

Waste Identification

All the chemical constituents in each hazardous waste stream must be accurately identified by knowledgeable laboratory personnel. *This is a critical safety issue for both laboratory users and the hazardous waste program personnel that collect and process the waste.* Mixing of incompatible waste streams has the potential to create violent reactions and is a common cause of laboratory accidents. If there is uncertainty about the composition of a waste stream resulting from an experimental process, laboratory workers must consult the PI/Laboratory Supervisor or the Chemical Hygiene Officer. In most cases, careful documentation and review of all chemicals products used in the experimental protocol will result in accurate waste stream characterization.

For commercial mixtures, the manufacturer's SDS provides detailed information on each hazardous ingredient present, and also the chemical, physical, and toxicological properties of the ingredient. The UCSB EH&S website provides access to SDS's for hazardous chemicals.

Labeling

Every container must be appropriately labeled per hazardous waste program requirements. These include:

- Use the official campus hazardous waste label and provide all necessary information.
- All hazardous waste containers must be labeled with the words 'Hazardous Waste'.
- All unknowns must be analyzed and their hazardous components identified at the generator's expense. Do not lose track of container contents!
- Waste must be identified by chemical name in English. Labels such as 'Inorganic Waste' and 'Organic Waste' are not adequate. Do not use abbreviations, acronyms, or chemical formulas.
- All constituents in solid and liquid mixtures must be identified, and to the extent possible their concentrations stated.
- The chemical hazard class of the waste must be identified (e.g. flammable, corrosive, oxidizer, etc.)
- Any preexisting labels on the container must be defaced either by removal or by crossing out the information.
- *All containers must be dated with the date on which waste was first stored in the container*. Under no circumstances store hazardous waste in the laboratory for more than 270 days (about 9 months).

Storage

The hazardous waste storage area in each laboratory is considered a Satellite Accumulation Area (SAA) by the EPA. According to EPA requirements, this area must remain under the control of the persons producing the waste. This mean that is should be located in an area that is supervised and is not accessible to the public. Other requirement include:

- Waste must be collected and stored at or near the point of generation.
- According to state law, the maximum amount of waste that can be stored in an SAA is 55 gallons of hazardous waste or 1 quart of extremely hazardous waste. If these volumes are met, the waste must be disposed of within 3 days.
- According to the California Fire Code, the maximum amount of flammable solvents allowed to be stored in a laboratory outside a flammable storage cabinet is 10 gallons. *This figure includes accumulated waste*.
- All waste containers must be kept closed when not in use. Containers should be designed so they can be completely sealed when not in use (no open-top glassware).
- Waste containers must be appropriate for the waste being stored in it. (e.g. do not use a glass container for hydrofluoric acid waste), and the waste streams segregated into compatible constituents.
- Oxidizing inorganic wastes (e.g. nitric acid, chromic acid, perchloric acid) or pressure generating wastes (e.g. piranha etch, aqua regia) must be stored with vented caps (contact EH&S for free vented caps).
- Liquid waste should be in screw top containers, and not be filled over 80%. Secondary containment should be used at all times.
- Outside surfaces of containers must be clean and free of contamination.
- Gas cylinders and lecture bottles must have regulators removed.
- Sharps must be stored in puncture-proof containers.
- Store containers in a designated location (low traffic, safe, secure, contained, etc.). Label this storage area as 'Hazardous Waste Storage Area'.

Segregation

All hazardous waste must be managed in a manner that prevents spills and unexpected reactions. Additionally, proper waste segregation can help reduce disposal costs. Proper segregation procedure includes:

- Segregate solids, liquids and gases.

- Further segregate into the following categories:
  - Halogenated Organics
  - Non-halogenated Organics
  - Acids of pH < 2
  - Bases of pH > 12.5
  - Alkali metals/other water reactive
  - Heavy metal solutions & salts
  - Strong oxidizers
  - Peroxide formers
  - Cyanides
  - Chemical Carcinogens
  - Unstable chemicals
  - Other toxic materials

Incompatible Waste Streams

Mixing incompatible waste streams, or selecting a container that is not compatible with its contents, is a common cause of accidents in laboratories and waste storage facilities. ***Reactive mixtures can rupture containers and explode, resulting in serious injury and property damage***. All chemical constituents and their waste byproducts must be compatible for each waste container generated. Waste tags must be immediately updated when a new constituent is added to a mixed waste container, so that others in the laboratory will be aware and manage it accordingly.

A common incompatible waste stream is the addition of nitric acid to a waste container containing organic solvent. This creates a very exothermic reaction and cause catastrophic container failure/large explosion. Extreme care should be taken with nitric acid waste. Store in dedicated small waste bottles, label them clearly, and dispose of them quickly.

Waste Which Requires Special Handling

Sharps and Laboratory Glass Waste

Sharps waste includes any device having acute rigid corners, edges, or protuberances capable of cutting or piercing, including but not limited to hypodermic needles, syringes, razor blades and scalpel blades. Glass items contaminated with biohazards, such as pipettes, microscope slides and capillary tubes are also considered sharps waste. Under no circumstances may sharps waste be disposed of in the normal trash. Sharps waste containers must be rigid, puncture-resistant, lidded and leak-proof when sealed.

Laboratory glass is defined as equipment made of Pyrex, borosilicate, and quarts glass used for scientific experiments. Examples of laboratory glass include beakers, flasks, graduated cylinders, stirring rods, test tubes, microscope slides, glass pipettes, petri dishes and glass vials. This waste should be disposed of in a cardboard lab glass box. *All glassware must be free of pourable liquid and must not contain sludges or caked solids. Glass items contaminated with biohazards are considered sharps waste (see paragraph above)*.

Further details on how to manage sharps and lab glass waste can be found in the EH&S Laboratory Sharps Fact Sheet.

Peroxide Forming Chemicals

Ensure containers of peroxide forming chemicals are kept tightly sealed to avoid unnecessary evaporation, as this inhibits the stabilizers that are sometimes added. Visually inspect containers periodically to ensure they are free of exterior contamination or crystallization. *Dispose of containers of peroxide forming chemicals before their expiration date*.

If old containers of peroxide forming chemicals are discovered in the laboratory (greater than five years past the expiration date or if the expiration date is unknown), **do not handle the container**. If crystallization is present in or on the container, **do not handle the container**. *Secure the area and contact EH&S immediately*.

Picric acid (trinitrophenol) must be kept hydrated at all times, as it becomes increasingly unstable as it loses water content. **When dehydrated it is explosive and sensitive to shock, heat, and friction**. It is also highly reactive with a variety of compounds. All picric acid containers should be dated with the date received, and the water content monitored every 6 months. Add distilled water as needed to maintain a consistent liquid volume.

If old containers or containers of unknown provenance are discovered, **do not touch the container**. Even a minor disturbance could be very dangerous. Visually inspect the bottle. If there is even the slightest sign of crystallization in or on the bottle, or of evaporation, *secure the area and contact EH&S immediately*.

Explosives and other Compounds with Shipping Restrictions

A variety of compounds that are classified as explosives (e.g. many nitro- and azo- compounds) or are water or air reactive are used in research laboratories. These compounds often have shipping restrictions and special packaging requirements, and may require stabilization prior to disposal. Consult with the Chemical Hygiene Officer for disposal considerations for these compounds.

Controlled Substances

Waste containing intact controlled substances (e.g. expired ketamine) must be disposed of by DEA approved means. Contact the UCSB Controlled Substances Program for guidance.

Empty Containers

Empty containers that held extremely hazardous materials, including extremely hazardous waste must be disposed of through EH&S, as these containers are regulated as hazardous waste. All other containers of less than or equal to 5 gallons should be reused for hazardous waste collection, recycled or disposed of. For more details, see the EH&S Empty Containers Fact Sheet.

Hazardous Waste Minimization

The UC Santa Barbara Hazardous Waste Minimization Program has the goal of reducing the amount and toxicity of waste generated through university activities. In addition to reducing risk to human health and the environment, waste minimization offers cost benefits in the form of avoided chemical purchasing and disposal costs. Some approaches to waste minimization include:

Source Reduction

Changing practices and processes in order to reduce or eliminate the generation of hazardous waste is the best approach to waste minimization. This approach can include:

- Effective Purchasing: Order smaller volumes to avoid chemical expiration/degradation. Maintain an accurate chemical inventory to avoid duplicate orders.

- Good Housekeeping: Use a 'first in-first out' system in which the oldest chemicals are used first, to keep chemical stocks rotated.

- Chemical Substitution: Evaluate processes to determine whether a less hazardous chemical can be used in place of a more hazardous option.

- Scale Reduction: Reduce total volumes in experiments; employ microscale techniques where possible. Use instrumental analytical methods rather than wet chemical techniques.

Recycling and Bench Top Treatment

When source reduction is not possible, recycling is the next best approach to waste minimization. Recycling of waste can take place both on and off campus and can include using a waste material for another purpose, treating a waste material and using it in the same process, or reclaiming a waste material for another process. Some examples include:

- Repurifying used solvents.

- Recirculating unused or surplus chemicals within your department or through the UCSB Surplus Chemicals program.

- Shipment of flammable liquid waste to offsite facilities, such as cement kilns, to be used as supplemental fuels.

Some waste can be treated to render it less or non-hazardous. Some examples include:

- Neutralizing acids and bases.

- Polymerizing acrylamide solutions.

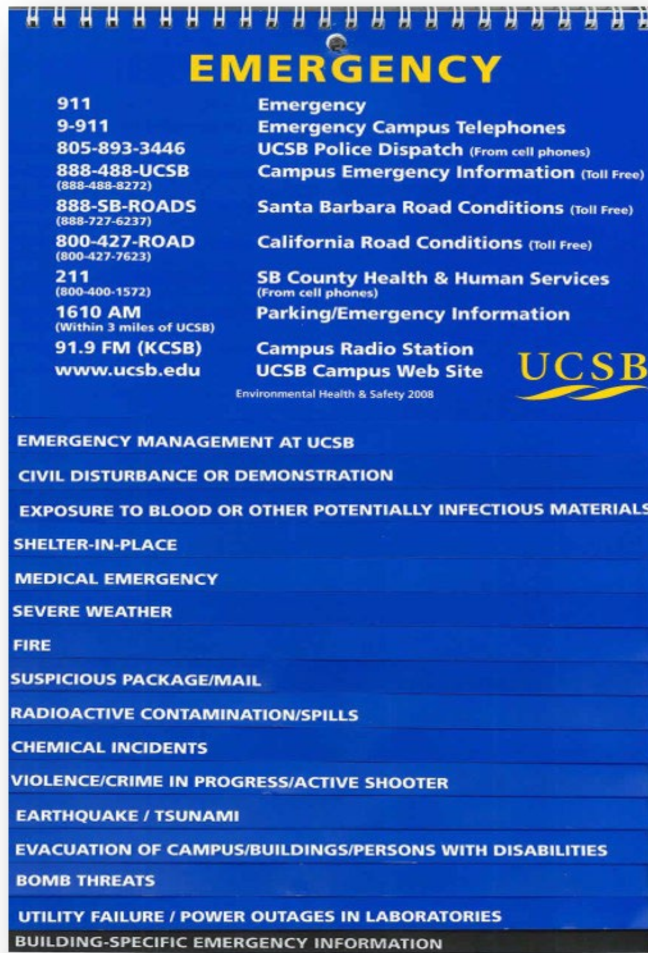
- Oxidizing cyanide salts with bleach solutions.

- Charcoal filtration of ethidium bromide solutions.

Note: if treatment is not part of the end step of an experiment and is done separately from the experiment, it is considered hazardous waste treatment. This treatment activity requires a California Tiered Permit unless the activities comply with Health and Safety Code 2200.3.1. As such, please contact EH&S if you plan to conduct any bench-top treatment of waste.

Chapter 4: Emergencies

Laboratory emergencies include events such as serious injuries, fires, explosions, spills, hazard exposures and natural disasters. All laboratory employees should be familiar with and aware of the location of the blue UCSB Emergency Flip Chart. This document has detailed response information for a wide variety of emergency situations. There should be one flip chart in every laboratory room or bay. Contact EH&S if additional copies of this document are needed. Before beginning any laboratory operation, ensure that there is a plan in place to deal with any potential emergency situations. Identify the location of safety equipment including first aid kits, eye wash/safety shower units, fire extinguishers, fire alarm pull stations, and spill kits. Know the locations of the nearest exits and telephones. See the following sections for more guidance on when an emergency response is warranted. However, *when in doubt, treat the situation as an emergency*.



If during an emergency or response, an unknown or hazardous chemical exposure occurs, an exposure assessment may be necessary. All applicable exposure assessment protocols will therefore be activated at that time.

Accidents

TREATMENT:

LABORATORY INJURY OR EXPOSURE

EMPLOYEES *(Getting paid by UC at time of incident)*	STUDENTS *(Getting paid by UC at time of incident)*	EVERYONE ELSE
Sansum Clinic Occupational Medicine (805) 898-3311 101 S Patterson Ave Weekdays 8 am to 5 pm	Student Health (805) 893-7129 or (805) 893-3371 Located on El Colegio and Mesa Rds., across from the Events Center. Weekdays 9 am to 4:30 pm	Go to your personal medical provider

AFTER HOURS AND IMMEDIATE TREATMENT FOR EVERYONE

URGENT CARE	Goleta Valley Cottage Hospital	Santa Barbara Cottage Hospital
(805) 563-6110 Sansum Clinic, 215 Pesetas Lane Monday - Friday, 8:00am - 7:00pm Saturday, 9:00am - 5:00pm Sunday, 9:00am - 3:00 pm (USE ONLY WHEN PATTERSON OFFICE IS CLOSED)	(805) 967-3411 351 S. Patterson Ave Open 24 hours (USE FOR EMERGENCIES)	(805) 682-7111 Pueblo at Bath Open 24 hours (USE FOR EMERGENCIES)

NOTICES

Explain Exposure: Be prepared to communicate exposure details (e.g., chemical name, biohazard) to medical providers.
Transportation: Arrange an escort when possible. For non-emergencies, you may use a personal vehicle instead of taking an ambulance.
Report: Work related injury/illness claims should be filed as soon as possible at ehs.ucop.edu/efr
For students fill out Notice of Incident Form available at https://www.ehs.ucsb.edu/
Near miss report form available at https://www.ehs.ucsb.edu/

CALL 911 IF EMERGENCY OR LIFE THREATENING

- Laboratory employees who are injured or ill should notify their PI/Laboratory Supervisor immediately, and then seek medical attention if needed. **When in doubt, seek medical attention**.

- Each laboratory should prepare for emergencies by, at minimum:
  - Access to a first aid kit.
  - Posting of emergency telephone numbers and locations of emergency treatment facilities and occupational health facilities.
  - Training of staff to:

- Assist injured personnel with the emergency eyewash/shower and ensure that they flush exposed areas for a full 15 minutes.
- Accompany injured personnel to the medical treatment site and to provide medical personnel with copies of Safety Data Sheets (SDS) for the chemicals involved in the incident.

If an employee has a severe or life threatening injury, call for emergency response. Employees with minor injuries should be treated with first aid kits and sent to Sansum Clinic Occupational Medicine. If the lab worker is a student (i.e. not on UCSB payroll), then they should go to Student Health for service. After normal business hours, treatment can be obtained at Goleta Valley or Santa Barbara Cottage Hospital.

REPORTING:

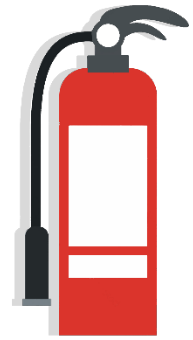
- PIs/Laboratory Supervisors are responsible for ensuring that their employees receive appropriate medical attention in the event of an occupational injury or illness. The PI/Laboratory Supervisor should call Workers' Compensation (805-893-4440) immediately if an employee seeks medical treatment, followed by creating a claim through the Employee First Report (EFR) system.

- **Serious occupational injuries, illnesses, and exposures to hazardous substances must be reported to EH&S at 805-893-3194 within 8 hours.** EH&S is required to report these events to Cal/OSHA, and will also investigate the accident and complete exposure monitoring as necessary. Serious injuries are defined as those that result in permanent impairment or disfigurement, or require hospitalization. Examples include amputations, lacerations with severe bleeding, burns, concussions, fractures and crush injuries.

Laboratory Safety Equipment

New personnel must be instructed in the location and use of fire extinguishers, safety showers, and other safety equipment *before* they begin work in the laboratory. This training is part of the required laboratory specific training that is documented on the Training Needs Assessment Form. Hands-on fire extinguisher training is provided during the live Fundamentals of Laboratory Safety course, as well as upon request.

Fire Extinguishers



All laboratories working with combustible or flammable chemicals must be outfitted with appropriate fire extinguishers. All extinguishers should be wall-mounted in an area free of clutter, or stored in a fire extinguisher cabinet. Research personnel should be familiar with the location, use and classification of the extinguishers in their laboratory. Laboratory personnel are ***not required*** to extinguish fires that occur in their work areas and should not attempt to do so unless:

- It is a small fire (small trash can-sized or smaller).
- Hands-on fire extinguisher training has been received.
- It is safe to do so.
- The individual wishes to do so.

Any time a fire extinguisher is discharged, no matter what the reason or how brief a period, EH&S must be contacted. Once partially discharged, an extinguisher will lose pressure quickly and therefore must be replaced as soon as possible.

Safety Shower/Eyewash Stations

All laboratories using hazardous chemicals must have immediate access to safety shower/eyewash stations. Access must be available in 10 seconds or less for a potentially injured individual, and access routes must have no more than one intervening door, opening in the direction of travel, and must be kept clear at all times. Safety showers require a minimum clearance of 16 inches from the centerline of the spray pattern in all directions and at all times. *Therefore, no objects should be stored within 16 inches of a safety shower*. Sink-based eyewash stations and drench hoses are not adequate to meet this requirement and can only be used to support an existing compliant system.

In the event of an emergency, individuals using the safety shower should be assisted by an uninjured person to aid in decontamination, and should be encouraged to stay in the shower for a full 15 minutes.

Safety shower/eyewash stations are tested by Facilities Management on a monthly basis. If a safety shower/eyewash unit appears to need repair, call Facilities Management Customer Service at 805-893-8300.

Fire Doors

Research buildings contain critical fire doors as part of the building design. As an important element of the building fire containment system, these doors shall remain closed unless they are held open by an electromagnetic releasing system integrated with the building fire detection system. Never use door stops to hold fire doors open.

Fire-Related Emergencies

If you encounter a fire, or a fire-related emergency (e.g. abno0rmal heating, smoke, burning odor), immediately follow these instructions:

- Pull the closest fire alarm pull station and call 911 to notify the Fire Department.
- Evacuate and isolate the area. Close all doors. Shut off equipment if feasible.
- Remain safely outside the affected area to provide details to emergency responders (do not leave).

If you hear a fire alarm sound, evacuate the building. *It is against state law to remain in the building when the alarm is sounding*, even if it is a false alarm or drill. Do not reenter the building until the alarm stops and you are cleared to reenter by Fire Department personnel.

If your clothing catches fire, go to the nearest emergency shower and activate the water flow. If the shower is more than 3 steps away, Stop, Drop and Roll, then proceed to the nearest shower to cool off. A fire extinguisher may be used to extinguish a fire on someone's person. Report any burn injury to your supervisor immediately and seek medical treatment.

Chemical Spills

For all spill releases occurring during regular work hours (8:00am-5:00pm), notify EH&S at (805)893-3194 immediately, regardless of whether you require clean-up assistance. **After hours, if the spill is not easily contained, or if you are concerned about the health and safety of yourself and others, call 911.** Otherwise notify EH&S at (805)893-3194 as described above.

Chemical spills can result in chemical exposures and contaminations. Chemical spills become emergencies when:

- The spill results in injury and/or a release to the environment (e.g. via a sink or floor drain).

- The material or its hazards are unknown.

- Laboratory personnel cannot safely manage the situation due to high hazard or volumes greater than one liter.

Effective response to chemical spills is necessary to minimize adverse outcomes such as injury, illness, or environmental damage. After emergency procedures are completed, all personnel involved in the incident should follow UCSB chemical exposure procedures as appropriate (see Chemical Exposures: Limits, Assessments, and Medical Evaluations in Chapter 3 of this document). Some key factors to consider before initiating a spill clean-up include:

- Location
- Volume/size of spill area
- Toxicity
- Volatility
- Flammability and presence of ignition sources
- Availability of spill cleanup materials, including proper PPE
- Training of responders

NOTE: HIGHLY HAZARDOUS CHEMICAL SPILLS

Do not clean up spills of any size of the following chemicals:

- **Aromatic amines**
- **Carbon disulfide**
- **Cyanides**
- **Ethers**
- **Mercury**
- **Hydrazine**
- **Hydrofluoric acid**
- **Nitriles**
- **Nitro compounds**
- **Organic halides**

Spills of these chemicals require emergency response.

Evacuate, isolate the area and contact EH&S.

Small Chemical Spill Procedure (< 1 Liter)

If a spill is up to 1 liter in size and of limited toxicity, flammability and volatility, laboratory members may choose to effect clean-up if trained to do. EH&S may be called for spills of < 1 liter. If laboratory personnel choose to clean the spill, the following procedure should be followed:

- Evacuate all non-essential persons from the spill area.

- If needed, call for medical assistance by calling 911.

- Help anyone who may have been contaminated. Assist with shower/eyewash as needed.

- Post someone just outside of the spill area to keep people from entering.

- Turn off all ignitions sources, and close valves on compressed gas cylinders of flammable gas.

- Don proper PPE: Safety goggles, laboratory coat, shoe covers and appropriate gloves at minimum. Check the SDS for spill clean-up procedures including necessary PPE or call EH&S.

- Avoid breathing vapors from the spill. If the spill is in a non-ventilated area, do not attempt the clean-up. Evacuate, isolate the area and call EH&S.

- Confine the spill to as small an area as possible by treating it from the outside edges in.

- Do not clean up the spill alone. Use the buddy system.

- Do not add water to the spill.

- To clean up a spill of weak inorganic acid or base, neutralized the spilled liquid to pH = 5-8 us in a neutralizing agent such as sodium bicarbonate, sodium bisulfate, or soda ash for spilled acids, or citric acid for spilled bases. For solvent spills skip to the next step.

- Absorb the neutralized liquid or solvent with an absorbent such as sorbent pads, sponges, paper towels, dry sand or diatomaceous earth.

- Collect the absorbents and place in a clear plastic bag. Double bag the waste and attach a completed hazardous waste label to the bag. Transport to the waste pickup area and schedule a pickup.

Large Chemical Spill Procedure (> 1 Liter)

If the spill presents a situation that is immediately dangerous to life or health or presents a significant fire risk, activate a fire alarm, evacuate the area, call 911 and wait for emergency response to arrive. Otherwise

- Remove any injured and/or contaminated person(s) and provide first aid.

- Call for emergency medical response if needed.

- As you evacuate the laboratory, close the door behind you, and:

    - Post someone safely outside and away from the spill area to keep people from entering.
    - Confine the spill area if possible and safe to do so.
    - Leave on or establish exhaust ventilation

    - If possible, if the material is flammable, turn off or remove all ignition sources.
    - Avoid walking through contaminated areas or breathing vapors of the spilled materials.
- Any employee with known contact with a particularly hazardous chemical must shower, including washing of hair, as soon as possible unless contraindicated by physical injuries.

Chemical Exposure to Personnel

In the event of a significant chemical exposure:

- immediately try to remove or isolate the chemical if safe to do so.
- When skin or eye exposures occur, remove contaminated clothing and flush the affected area using an eyewash/shower unit *for at least 15 minutes*.
- Remember to wear appropriate PPE when helping others.
- For a non-emergency chemical ingestion, inhalation or dermal exposure contact the California Poison Control System at 1-800-222-1222 for assistance, and seek medical care as instructed.

PIs/Laboratory Supervisors must review all exposure situations, make sure affected employees receive appropriate medical treatment and/or assessment, and arrange for containment and clean-up of the chemical as appropriate (either by laboratory personnel or by contacting EH&S).

Earthquake

In the event of an earthquake, please take the following precautions:

- Prepare in advance: be familiar with your department's Emergency Action Plan.
- Take cover under a desk or strong doorframe during the shaking.
- Remain under cover indoors until the shaking subsides. Evacuate the building only once the shaking has ceased. Proceed to your building's emergency assembly point.
- Report any injuries or broken utility services to 911.
- Assist any injured individuals with receiving medical attention.

Chapter 5: Compliance

Recordkeeping Requirements

Accurate recordkeeping demonstrates a commitment to the health and safety of the UC Santa Barbara community, integrity of research, and protection of the environment. EH&S is responsible for maintaining records of the Laboratory Safety Reviews, all laboratory audits and surveys, accident investigations, monitoring equipment calibration and exposure assessment data, inventory and use records for high-hazard materials, any medical consultation and examination records, including test or written opinions, and training conducted by EH&S staff or on line. Per Cal/OSHA regulations, departments or laboratories are responsible for documenting departmental or lab specific health and safety training. The Training Needs Assessment Form is a useful tool for documenting each person's training record.

Notification and Accountability

PI's/Laboratory Supervisors are responsible for taking appropriate and effective corrective action upon receipt of written notification of findings requiring resolution that are identified via lab safety reviews, audits, surveys or inspections. Findings are assigned one of four priority levels, each with its own timeframe for resolution:

> **Imminent Danger** (Immediate danger to life and health, significant property damage, serious near-miss incidents involving conditions that are likely present in other locations on campus.): Immediate Resolution/Stop Work.
>
> **Priority One** (Serious safety hazard, serious/willful regulatory violations and/or significant fire and life safety code violation): Closure within 0-5 days
>
> **Priority Two** (Moderate safety hazard or moderate/repeat regulatory violation and/or moderate fire and life safety concern/housekeeping/documentation issues, etc.): Closure within 6-30 days
>
> **Priority Three:** Closure within 31-90 days (minimal safety hazard/ possible regulatory violation, infrastructure, deferred maintenance, etc.)

The determination of prioritization is subjective based on the inspector's judgment. Every situation is unique; EHS inspectors will base inspection findings on a review of relevant hazards, codes and exposures.

Compliance Procedures

Reminder emails will be sent to the PI/Laboratory Supervisor after the initial report is sent. Repeat issue of non-compliance, identified via scheduled inspection or otherwise, include but are not limited to:

- Any Serious (Priority 2) findings that have not been corrected within 30 calendar days of the initial report of non-compliance.
- Any urgent (Priority 1) findings that have not been corrected within 5 days of the initial report on non-compliance.

When the above conditions are met, the following escalation protocols are initiated:

Priority 2 (Serious) Escalation Protocol

Escalation 1: Email notification sent to Department Chair at 4 weeks:

Dear Prof. [ ],

This letter is to inform you that Prof. [ ] has outstanding serious findings in the most recent Environmental Health and Safety laboratory inspection. Our standard practice for serious findings is to remind the responsible party to correct the findings and update the INSPECT database twice, in two week intervals, before escalating the issue to the department chair. That period has now expired.

Please remind Prof [ ] that addressing safety issues and documenting corrections is a key part of sustaining a safe and compliant laboratory culture, and request that they complete the corrections and update the INSPECT database as soon as possible.

Thank you,

Escalation 2: Email to Department Chair at 6 weeks:

Dear Prof. [ ],

This letter is to inform you that Prof. [ ] still has outstanding serious findings in the most recent Environmental Health and Safety laboratory inspection. This is our second notification to you regarding this issue. Our standard practice in this situation is to send a second notification to the department chair, followed by escalation to the Dean if the matter is not resolved within two weeks of this notice.

Please remind Prof [ ] that addressing safety issues and documenting corrections is a key part of sustaining a safe and compliant laboratory culture, and request that they complete the corrections and update the INSPECT database as soon as possible.

Thank you,

Escalation 3: Email to Dean at 8 weeks:

Dear Dean [ ],

This letter is to inform you that Prof. [ ] has outstanding serious findings in the most recent Environmental Health and Safety laboratory inspection. Our standard practice for serious *findings is to remind the responsible party to correct the findings and update the INSPECT database twice, in two week intervals, before escalating the issue to the department chair. As the matter is still not resolved upon contacting the department chair, we are reaching out to you for assistance in getting this matter resolved.*

Please remind Prof [ ] that addressing safety issues and documenting corrections is a key part of sustaining a safe and compliant laboratory culture, and request that they complete the corrections and update the INSPECT database as soon as possible.

Thank you

Escalation 4: Refer the issue to the Chemical and Physical Hazard Safety Committee.

Priority 1 (Urgent)

Escalation 1: Email to Department Chair at 5 days:

Dear Prof. [ ],

This letter is to inform you that Prof. [ ] has outstanding urgent findings in the most recent Environmental Health and Safety laboratory inspection. Our standard practice for urgent findings is to remind the responsible party to correct the findings and update the INSPECT database once, five days after the initial notification, before escalating the issue to the department chair. That period has now expired.

Please remind Prof [ ] that addressing safety issues and documenting corrections is a key part of sustaining a safe and compliant laboratory culture, and request that they complete the corrections and update the INSPECT database as soon as possible. The matter will be escalated to the Dean if the matter is not resolved within two days of this notice.

Thank you,

Escalation 2: Email to Dean at 7 days:

Dear Dean [ ],

This letter is to inform you that Prof. Y has outstanding urgent findings in the most recent Environmental Health and Safety laboratory inspection. Our standard practice for urgent findings is to remind the responsible party to correct the findings and update the INSPECT database five days after the initial notification, before escalating the issue to the department chair. As the matter is still not resolved upon contacting the department chair, we are reaching out to you for assistance in getting this matter resolved.

Please remind Prof [ ] that addressing safety issues and documenting corrections is a key part of sustaining a safe and compliant laboratory culture, and request that they complete the corrections and update the INSPECT database as soon as possible.

Thank you,

Escalation 3: Refer the issue to the Chemical and Physical Hazard Safety Committee.

Acknowledgements

UC Santa Barbara would like to thank the UCLA Office of Environmental Health & Safety. This document was created using the UCLA Chemical Hygiene Plan 2019 as a major source of content.

This document was reviewed, edited and approved by the UC Santa Barbara Chemical and Physical Hazards Safety Committee, Prof. Christopher Palmstrøm, Chair.

This page intentionally left blank

UCSB Laboratory Safety Manual and Chemical Hygiene Plan

Prepared by UCSB Environmental Health & Safety

SECTION III (3):

REGULATORY FRAMEWORK

This section of the document is now provided to laboratories in an electronic version only – see URL (Web address) provided below.

Web address (URL) for Section III: http://www.ehs.ucsb.edu/labsafety-chp/

Per Cal-OSHA requirements, this document needs to be reviewed and updated ***annually****. Therefore, please refer to the web version for the most recent update. The PDF and hardcopy versions of this CHP contain the version of Section III that is current as of the date of the last revision of this CHP. This version of Section III is only provided for your convenience, without implying that it is the current version.*

Questions can be directed to Alex Moretto at amoretto@ucsb.edu

See also the Table of Contents – UCSB Chemical Hygiene Plan webpage at

https://www.ehs.ucsb.edu/programs-services/lab-safety-chemical-hygiene/labsafety-chp

This page intentionally left blank

UC SANTA BARBARA

CHEMICAL HYGIENE PLAN

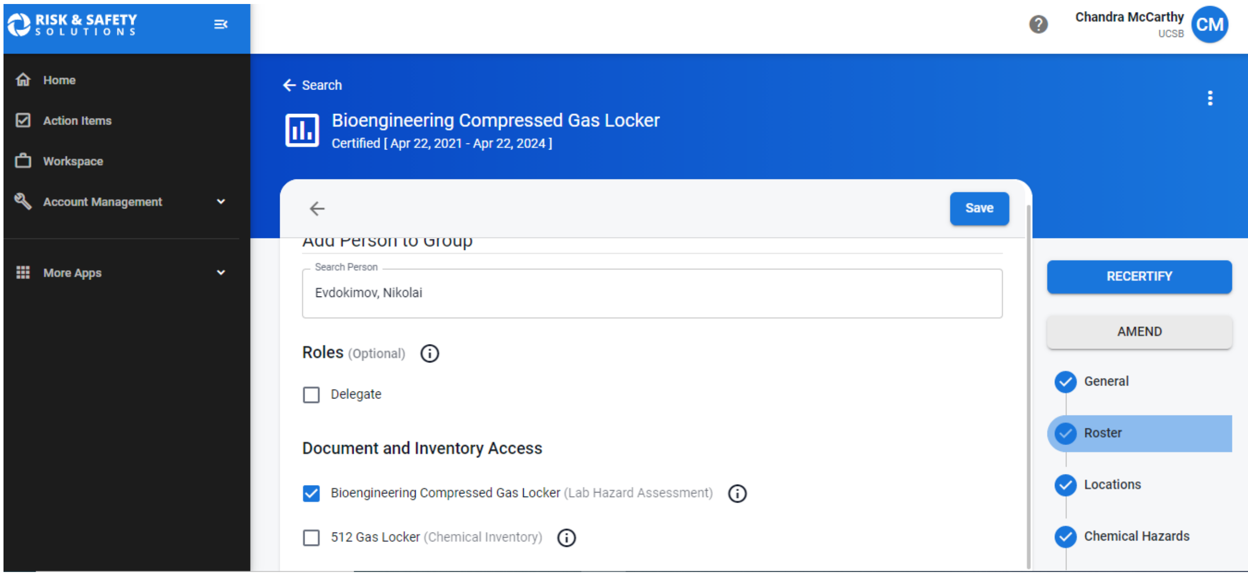
Appendix

Laboratory Supervisor and Principal Investigator Responsibilities

(For new PIs)

1. **Fundamentals of Laboratory Safety:** Please ensure all lab workers have taken either the live or online version of the course before they begin work in the laboratory.

2. **Create a Laboratory Hazard Assessment:**
   - Login to Assessment (LHAT) using your campus credentials.
   - From the RSS Home Page, click ***Begin A Laboratory Hazard Assessment***
   - Follow the prompts and click ***Certify***
   - Once certified, you may add lab members to your **Roster** by clicking on "Roster" from the right side menu, then click on the plus icon to the bottom right. Type the last name of the new member in the search *for person* window until the name & email populates(click on the populated name/email), you will see something like this:



Click **Save** to add the member. (Note, before you click Save, you will have the option to assign the member as a delegate and/or a UC Chemical Inventory member, by checking the appropriate box).

- Upon adding a new member to the roster, the lab Member will receive an email notification requiring them to acknowledge the assessment and complete the PPE training & quiz. Once the PPE training/quiz is completed (next Steps), the member will schedule an appointment via the PPE Google Calendar to pick up their free PPE (2 lab coats & eyewear). For more information regarding PPE refer to the Laboratory Personal Protective Equipment section of the EH&S website.

3. **Training Needs Assessment form:** Please ensure lab workers have completed a Training Needs Assessment. Retain a copy of the completed, signed and dated TNA form for documentation (e.g. keep copies in the Chemical Hygiene Plan binder or similar).

4. **Laboratory-Specific Chemical Hygiene Plan:** PI/Supervisors are required to maintain a copy of their Chemical Hygiene Plan. EH&S will provide you with a binder, which includes three sections. Section I is lab specific and should include Standard Operating Procedures(SOPs) for safe work with hazardous materials and/or processes. You may print the CHP from our website (click on hyperlink above). Ensure the lab worker has reviewed sections I&II of your lab's Chemical Hygiene Plan and signed the Laboratory Worker Training Record found in Section I. Ensure you have the latest version of Sections II & III of the CHP and that you have created/added/and-or updated the SOPs in your CHP. You may use Standard Operating Procedure templates located in the EH&S website. To view the policy regarding CHP go to http://www.ehs.ucsb.edu/labsafety-chp

5. **OSHA's Occupational Exposure Limits:** Please refer to the Industrial Hygiene section of the EH&S website regarding occupational exposure limits.

6. **Authorization Coordinated by EH&S:**
    - The Institutional Biosafety Committee reviews and approves work with human tissues, infectious agents - Contact Jamie Bishop. For more information and resources regarding Biological Safety visit: https://www.ehs.ucsb.edu/biosafety

- The Dive Safety Committee reviews and approves work out in the open ocean - Contact Eric Hessell. For more information and resources regarding Dive & Boat Safety visit: https://www.ehs.ucsb.edu/dive
- The EH&S controlled substance coordinator assists with DEA licenses for work with Schedule I - Contact Derek Iverson.
- The Radiation Safety officer maintains inventory of all class 3b and 4 laser systems - Contact Robert Brown. For more information and resources regarding Radiation Safety visit: https://www.ehs.ucsb.edu/rad
- The Research & Occupational Specialist approves Chemical Storage Units - Contact Hector Acuna
- Respiratory Protection Program - For the use of face masks or dust masks, please contact Jesse Bickley jesse.bickley@ucsb.edu or Nick Nieberding nick.nieberding@ucsb.edu

7. **Safety Data Sheets:** Please review OSHA's requirements for maintaining SDSs in the work area and training laboratory workers on how to use SDSs.

8. **Fire & Door Placard, Incidents & Near Miss reporting, and UC Chemicals:**
    - Please maintain an Emergency Flip Chart in the lab(s). You may arrange to pick one up from EH&S (contact Chandra Mccarthy). Ensure the Building-Specific Emergency Information is completed and posted. Additionally we are required to post door placards for first responders in case of an emergency. Please let us know when there are changes to the hazards in the lab so that we may update the door placard. You may also complete a new door placard form and return to Chandra Mccarthy when there are changes or when creating a new placard for your lab.
    - Any incident in the lab must be reported. Incidents with serious injury (e.g. loss of body part, hospitalization, etc.) must be reported right away. Any other incident must be reported within 24 hours. You may report incidents through the EH&S online portal by clicking on the top right tab "Incident/Injury". Additionally, Near Misses should also be reported to provide information and lessons learned. You

may report a near miss through the EH&S online portal by clicking on the top middle tab "Near Miss". For more information regarding reporting incidents and near misses go to: Risk Management

- **UC Chemicals:** You may create an inventory in the UC application Chemicals by clicking *on Create a New Inventory* from the drop down box. For maintaining chemical inventory using the UC Chemicals application, EH&S will provide the lab group with scanner stickers that you can use/assign to chemicals and location. **I am happy to schedule an in person meeting to assist with this if/when you choose to use the program.*

9. **Hazardous Waste Management:** Please refer to the Hazardous Waste section of the EH&S website regarding *UCSB guidelines for HW management and sharps disposal; and Universal Waste Procedures*

10. **Laboratory Safety Review (Inspection) program:** Typically the lab safety specialist assigned to your department would schedule a one-on-one meeting with the supervisor or delegate to conduct a lab safety review which entails (1) Review of administrative controls (2) physical space inspection. However, due to the current health guidelines and COVID mitigation, lab safety reviews are conducted without a lab representative. For more information regarding our Inspection program please go to Laboratory Safety Review Program.

*Note: Beginning January 2022 EH&S will resume the in-person lab safety review.

11. **Minors in Laboratory and Shops Policy**
    - Please review the policy Here

12. **Spill Kit & First Aid "Be Smart About Safety"**
    In an effort to positively influence the safety culture on campus and develop a solid work relationship with faculty, each new PI is provided with an in-house assembled chemical spill kit and first aid kit. This Be Smart About Safety funded program, in addition to our established services, promotes a reduction in workers compensation claims, property damage, and time away from work. **Please let me know if you would like a spill kit or first aid kit or both and I will arrange to drop them off to the lab.*

For more information and resources please go to the EH&S website @

http://www.ehs.ucsb.edu/labsafety/safety-responsibilities-pis-and-supervisors

COVID-19 Information for Researchers:

https://www.ehs.ucsb.edu/labsafety/covid-19-information-researchers

ENVIRONMENTAL HEALTH AND SAFETY

University of California Santa Barbara

Research Safety Self-Inspection Checklist

Building and Lab Number:

Responsible Party:

Inspected by:

Date:

#	ITEM	Yes	No	N/A	Date Corrected
General Safety					
1	Housekeeping (is aisle space adequate - at least 3 foot clearance)? Are work spaces clean and tidy? Any excess trash? Combustible materials stored orderly and away from ignition sources? Floors clear with no slip (e.g. oil residue or water), trip or fall hazards?				
2	Is the Sanitation standard no food and drink in areas exposed to toxic materials being followed? No Food and/or Drink in a Lab Storage Refrigerator/Freezer?				
3	Other				
Emergency Preparedness and Fire Safety					
4	Emergency shower/eye wash station easily accessible?				
5	Are fire extinguishers easily available and accessible, tag indicates that they have been tested within the last year?				
6	Are all corridors and exits free of obstruction? Are all fire rated doors kept closed (no propped open doors). Mangnetic holders are acceptable.				
7	Is storage ceiling clearance within correct distances (2' for non-sprinkled buildings and 18" for sprinkled buildings)?				
8	Are sprinklers appear to be in good conditions? Are all constructions around the sprinkler in place (ceiling tiles, open holes and etc.)?				
9	Are Spill/First Aid Kits available? Are the contents of the kits re-stocked and within the shelf life? For Labs using Hydrofluoric Acid is Calcium Gluconate available and within the shelf life?				
10	All chemical spills or debris properly cleaned?				
11	Is the Emergency Flip Chart available? Building specific page customized?				
12	Is the door placard present and up-to-date?				
Seismic Safety					
13	Are all tall furniture and equipment (>42") braced? Are shelves used for chemical storage equipped with restrains? No overhead storage of heavy items?				
PPE					
14	Is PPE policy followed by all lab members? If respirators are worn, are users enrolled in the UCSB respiratory protection program?				
Gas Under Pressure					
15	Are gas cylinders: seismically anchored, hydrotested (<10 y), labeled with contents, capped when not in use, inventoried with a barcode, and kept in ventilated area? Any signs of corrosion? Is the applied tubing compatible with the material being used?				
16	Is emergency shutoff for flammable gases installed?				
17	Are oxygen cylinders separated from flammable gas by 20' or a noncombustible barrier at least 5' tall? (i.e. not near electrical or ignition sources, not under stairs.)				
Chemical Storage					
18	Are all chemical containers labeled and in a good condition? Are incompatible chemicals segregated?				
19	Are laboratory freezers clean and defrosted? Are flammables stored in a flammable materials storage (desparked) fridge/freezer?				
20	Are all peroxide formers dated and within the time allowed for storage/use?				
21	Are flammables stored in a flammable liquid storage cabinet? No more than ten 10 gallons of flammable or combustible liquids may be stored outside a flammable cabinet.				
22	Are chemicals stored in a designated storage area? Are there any chemicals stored on the floor or above eye level?				
Hazardous Waste Management					
23	Is the hazardous waste stored properly: capped, in designated area with secondary containment for liquid waste? Is incompatible waste segregated? Is the hazardous waste label completely filled out: chemical name, start date, physical state, chemical hazard clasification? Is the accumulation time less than 9 months?				
24	Is Universal waste (e.g. e-wate, batteries, light bulbs, etc.) properly stored and labeled (type of waste and date)? Is the accumulation time less than 1 year?				
25	Are sharps disposed of in a properly labeled, puncture proved container? Is the container fuller than 2/3rd of its volume?				
Electrical Safety					
26	Is the electrical panel kept closed and easily accessible at all times?				
27	Are all electrical cords in good condition (any frayed cords, tangled cords, tripping hazards)?				
28	Are extension cords used for temporary purpose only? Any daisy chain cords? Are multiple outlet strips equipped with circuit breaker?				
Fume Hoods (CCR Title 8/5154.1)					
29	Is the fume hood cleared of clutter, certified and properly used (sash level not above the safe working height; work area is 6" behind the sash)?				
Equipment Safety					
30	No open flame in a biosafety cabinet/laminar box?				
31	Is all the equipment in good working order with all safety features in place (hearing protection provided if sonicator is present; safety guards in place for moving parts, pinch points, belts; catching oil pans for vacuum pumps, clean and lubricated rotors of centrifuges and etc.)?				
32	Is all equipment labeled for use (research or food storage ; high voltage; not for flammable storage and etc.?)				

<u>For safety questions and conserns:</u>

EEMB, MSI, Bren School, Anthropology, Earth Science, NRS contact **Nelly.Traitcheva@ehs.ucsb.edu 805-893-5129**

Other departments contact: **Chandra.Feeser@ucsb.edu 805-893-3264**

GHS Classification

GHS, the Globally Harmonized System of Classification and Labeling of Chemicals, was developed by the United Nations as a way to bring into agreement the chemical regulations and standards of different countries. GHS includes criteria for the classification of health, physical and environmental hazards, as well as specifying what information should be included on labels of hazardous chemicals as well as safety data sheets. This page summarizes the relationship of GHS hazard statements, pictograms, signal words, hazard classes, categories, and precautionary statements.

Ref: UNECE GHS (Rev.8) (2019), UNECE GHS (Rev.7) (2017)

Hazard Class Pictograms

	Exploding Bomb Explosives GHS01		Flame Flammables GHS02		Flame Over Circle Oxidizers GHS03
	Gas Cylinder Compressed Gases GHS04		Corrosion Corrosives GHS05		Skull and Crossbones Acute Toxicity GHS06
	Exclamation Mark Irritant GHS07		Health Hazard GHS08		Environment GHS09

Note: All pictograms are shown in svg format in the page. The corresponding gif images are also available, e.g. https://pubchem.ncbi.nlm.nih.gov/images/ghs/GHS08.gif.

GHS Hazard Statements

Code	Hazard Statements	Hazard Class	Category	Pictogram	Signal Word	Precautionary Statements P-Codes			
						Prevention	Response	Storage	Disposal
H200	Unstable Explosive	Explosives	Unstable Explosive		Danger	P201, P202, P281	P372, P373, P380	P401	P501
H201	Explosive; mass explosion hazard	Explosives	Div 1.1		Danger	P210, P230, P240, P250, P280	P370+P380, P372, P373	P401	P501
H202	Explosive; severe projection hazard	Explosives	Div 1.2		Danger	P210, P230, P240, P250, P280	P370+P380, P372, P373	P401	P501
H203	Explosive; fire, blast or projection hazard	Explosives	Div 1.3		Danger	P210, P230, P240, P250, P280	P370+P380, P372, P373	P401	P501
H204	Fire or projection hazard	Explosives	Div 1.4		Warning	P210, P240, P250, P280	P370+P380, P372, P373, P374	P401	P501

H205	May mass explode in fire	Explosives	Div 1.5	None	Danger	P210, P230, P240, P250, P280	P370+P380, P372, P373	P401	P501
		Explosives	Div 1.6*						
H206	Fire, blast or projection hazard; increased risk of explosion if desensitizing agent is reduced	Desensitized explosives	Category 1		Danger	P210, P212, P230, P233, P280	P370+P380+P375	P401	P501
H207	Fire or projection hazard; increased risk of explosion if desensitizing agent is reduced	Desensitized explosives	Category 2		Danger	P210, P212, P230, P233, P280	P370+P380+P375	P401	P501
H207	Fire or projection hazard; increased risk of explosion if desensitizing agent is reduced	Desensitized explosives	Category 3		Warning	P210, P212, P230, P233, P280	P370+P380+P375	P401	P501
H208	Fire hazard; increased risk of explosion if desensitizing agent is reduced	Desensitized explosives	Category 4		Warning	P210, P212, P230, P233, P280	P371+P380+P375	P401	P501
H220	Extremely flammable gas	Flammable gases	1A: Flammable gas, Pyrophoric gas, Chemically unstable gas A,B		Danger	P210	P377, P381	P403	
H221	Flammable gas	Flammable gases	1B		Danger	P210	P377, P381	P403	
H221	Flammable gas	Flammable gases	Category 2	None	Warning	P210	P377, P381	P403	
H222	Extremely flammable aerosol	Aerosols	Category 1		Danger	P210, P211, P251		P410+P412	
H223	Flammable aerosol	Aerosols	Category 2		Warning	P210, P211, P251		P410+P412	

H224	Extremely flammable liquid and vapor	Flammable liquids	Category 1		Danger	P210, P233, P240, P241, P242, P243, P280	P303+P361+P353, P370+P378	P403+P235	P501
H225	Highly Flammable liquid and vapor	Flammable liquids	Category 2		Danger	P210, P233, P240, P241, P242, P243, P280	P303+P361+P353, P370+P378	P403+P235	P501
H226	Flammable liquid and vapor	Flammable liquids	Category 3		Warning	P210, P233, P240, P241, P242, P243, P280	P303+P361+P353, P370+P378	P403+P235	P501
H227	Combustible liquid	Flammable liquids	Category 4	None	Warning	P210, P280	P370+P378	P403+P235	P501
H228	Flammable solid	Flammable solids	Category 1		Danger	P210, P240, P241, P280	P370+P378		
H228	Flammable solid	Flammable solids	Category 2		Warning	P210, P240, P241, P280	P370+P378		
H229	Pressurized container: may burst if heated	Aerosols	Category 1		Danger	P210, P211, P251		P410+P412	
H229	Pressurized container: may burst if heated	Aerosols	Category 2		Warning	P210, P211, P251		P410+P412	
H229	Pressurized container: may burst if heated	Aerosols	Category 3	None	Warning	P210, P211, P251		P410+P412	
H230	May react explosively even in the absence of air	Flammable gases	1A, Chemically unstable gas A			P202			
H231	May react explosively even in the absence of air at elevated pressure and/or temperature	Flammable gases	1A, Chemically unstable gas B			P202			
H232	May ignite spontaneously if exposed to air	Flammable gases	1A, Pyrophoric gas		Danger	P222			
H240	Heating may cause an explosion	Self-reactive substances and mixtures; Organic peroxides	Type A		Danger	P210, P220, P234, P280	P370+P378, P370+P380+P375	P403+P235, P411, P420	P501

H241	Heating may cause a fire or explosion	Self-reactive substances and mixtures; Organic peroxides	Type B		Danger	P210, P220, P234, P280	P370+P378, P370+P380+P375	P403+P235, P411, P420	P501
H242	Heating may cause a fire	Self-reactive substances and mixtures; Organic peroxides	Type C, D		Danger	P210, P220, P234, P280	P370+P378	P403+P235, P411, P420	P501
H242	Heating may cause a fire	Self-reactive substances and mixtures; Organic peroxides	Type E, F		Warning	P210, P220, P234, P280	P370+P378	P403+P235, P411, P420	P501
		Self-reactive substances and mixtures; Organic peroxides	Type G						
H250	Catches fire spontaneously if exposed to air	Pyrophoric liquids; Pyrophoric solids	Category 1		Danger	P210, P222, P280	P302+P334, P370+P378	P422	
H251	Self-heating; may catch fire	Self-heating substances and mixtures	Category 1		Danger	P235+P410, P280		P407, P413, P420	
H252	Self-heating in large quantities; may catch fire	Self-heating substances and mixtures	Category 2		Warning	P235+P410, P280		P407, P413, P420	
H260	In contact with water releases flammable gases which may ignite spontaneously	Substances and mixtures which in contact with water, emit flammable gases	Category 1		Danger	P223, P231+P232, P280	P335+P334, P370+P378	P402+P404	P501
H261	In contact with water releases flammable gas	Substances and mixtures which in contact with water, emit flammable gases	Category 2		Danger	P223, P231+P232, P280	P335+P334, P370+P378	P402+P404	P501
H261	In contact with water releases flammable gas	Substances and mixtures which in contact with water, emit flammable gases	Category 3		Warning	P231+P232, P280	P370+P378	P402+P404	P501
H270	May cause or intensify fire; oxidizer	Oxidizing gases	Category 1		Danger	P220, P244	P370+P376	P403	
H271	May cause fire or explosion; strong Oxidizer	Oxidizing liquids; Oxidizing solids	Category 1		Danger	P210, P220, P221, P280, P283	P306+P360, P371+P380+P375, P370+P378		P501

H272	May intensify fire; oxidizer	Oxidizing liquids; Oxidizing solids	Category 2		Danger	P210, P220, P221, P280	P370+P378		P501
H272	May intensify fire; oxidizer	Oxidizing liquids; Oxidizing solids	Category 3		Warning	P210, P220, P221, P280	P370+P378		P501
H280	Contains gas under pressure; may explode if heated	Gases under pressure	Compressed gas, Liquefied gas, Dissolved gas		Warning			P410+P403	
H281	Contains refrigerated gas; may cause cryogenic burns or injury	Gases under pressure	Refrigerated liquefied gas		Warning	P282	P336, P315	P403	
H282	Extremely flammable chemical under pressure: may explode if heated	Chemicals under pressure	Category 1	 	Danger	P210, P211	P370+P378, P376, P381	P410+P403	
H283	Flammable chemical under pressure: may explode if heated	Chemicals under pressure	Category 2	 	Warning	P210, P211	P370+P378, P376, P381	P410+P403	
H284	Chemical under pressure: may explode if heated	Chemicals under pressure	Category 3		Warning	P210	P376	P410+P403	
H290	May be corrosive to metals	Corrosive to Metals	Category 1		Warning	P234	P390	P404	
H300	Fatal if swallowed	Acute toxicity, oral	Category 1, 2		Danger	P264, P270	P301+P310, P321, P330	P405	P501
H301	Toxic if swallowed	Acute toxicity, oral	Category 3		Danger	P264, P270	P301+P310, P321, P330	P405	P501
H302	Harmful if swallowed	Acute toxicity, oral	Category 4		Warning	P264, P270	P301+P312, P330		P501
H303	May be harmful if swallowed	Acute toxicity, oral	Category 5	None	Warning		P312		
H304	May be fatal if	Aspiration hazard	Category 1		Danger		P301+P310, P331	P405	P501

	swallowed and enters airways								
H305	May be fatal if swallowed and enters airways	Aspiration hazard	Category 2		Warning		P301+P310, P331	P405	P501
H310	Fatal in contact with skin	Acute toxicity, dermal	Category 1, 2		Danger	P262, P264, P270, P280	P302+P350, P310, P322, P361, P363	P405	P501
H311	Toxic in contact with skin	Acute toxicity, dermal	Category 3		Danger	P280	P302+P352, P312, P322, P361, P363	P405	P501
H312	Harmful in contact with skin	Acute toxicity, dermal	Category 4		Warning	P280	P302+P352, P312, P322, P363		P501
H313	May be harmful in contact with skin	Acute toxicity, dermal	Category 5	None			P312		
H314	Causes severe skin burns and eye damage	Skin corrosion/irritation	Category 1A, 1B, 1C		Danger	P260, P264, P280	P301+P330+P331, P303+P361+P353, P363, P304+P340, P310, P321, P305+P351+P338	P405	P501
H315	Causes skin irritation	Skin corrosion/irritation	Category 2		Warning	P264, P280	P302+P352, P321, P332+P313, P362		
H316	Causes mild skin irritation	Skin corrosion/irritation	Category 3	None	Warning		P332+P313		
H317	May cause an allergic skin reaction	Sensitization, Skin	Category 1, 1A, 1B		Warning	P261, P272, P280	P302+P352, P333+P313, P321, P363		P501
H318	Causes serious eye damage	Serious eye damage/eye irritation	Category 1		Danger	P280	P305+P351+P338, P310		
H319	Causes serious eye irritation	Serious eye damage/eye irritation	Category 2A		Warning	P264, P280	P305+P351+P338, P337+P313		
H320	Causes eye irritation	Serious eye damage/eye irritation	Category 2B	None	Warning	P264	P305+P351+P338, P337+P313		
H330	Fatal if inhaled	Acute toxicity, inhalation	Category 1, 2		Danger	P260, P271, P284	P304+P340, P310, P320	P403+P233, P405	P501
H331	Toxic if inhaled	Acute toxicity, inhalation	Category 3		Danger	P261, P271	P304+P340, P311, P321	P403+P233, P405	P501
H332	Harmful if inhaled	Acute toxicity, inhalation	Category 4		Warning	P261, P271	P304+P340, P312, P304+P312		

H333	May be harmful if inhaled	Acute toxicity, inhalation	Category 5	None	Warning	P261, P271	P304+P340, P312, P304+P312		
H334	May cause allergy or asthma symptoms or breathing difficulties if inhaled	Sensitization, respiratory	Category 1, 1A, 1B		Danger	P261, P285	P304+P341, P342+P311		P501
H335	May cause respiratory irritation	Specific target organ toxicity, single exposure; Respiratory tract irritation	Category 3		Warning	P261, P271	P304+P340, P312	P403+P233, P405	P501
H336	May cause drowsiness or dizziness	Specific target organ toxicity, single exposure; Narcotic effects	Category 3		Warning	P261, P271	P304+P340, P312	P403+P233, P405	P501
H340	May cause genetic defects	Germ cell mutagenicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501
H341	Suspected of causing genetic defects	Germ cell mutagenicity	Category 2		Warning	P201, P202, P281	P308+P313	P405	P501
H350	May cause cancer	Carcinogenicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501
H350i	May cause cancer by inhalation	Carcinogenicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501
H351	Suspected of causing cancer	Carcinogenicity	Category 2		Warning	P201, P202, P281	P308+P313	P405	P501
H360	May damage fertility or the unborn child	Reproductive toxicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501
H360F	May damage fertility	Reproductive toxicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501
H360D	May damage the unborn child	Reproductive toxicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501
H360FD	May damage fertility; May damage the unborn child	Reproductive toxicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501
H360Fd	May damage fertility; Suspected of damaging the unborn child	Reproductive toxicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501

H360Df	May damage the unborn child; Suspected of damaging fertility	Reproductive toxicity	Category 1A, 1B		Danger	P201, P202, P281	P308+P313	P405	P501
H361	Suspected of damaging fertility or the unborn child	Reproductive toxicity	Category 2		Warning	P201, P202, P281	P308+P313	P405	P501
H361f	Suspected of damaging fertility	Reproductive toxicity	Category 2		Warning	P201, P202, P281	P308+P313	P405	P501
H361d	Suspected of damaging the unborn child	Reproductive toxicity	Category 2		Warning	P201, P202, P281	P308+P313	P405	P501
H361fd	Suspected of damaging fertility; Suspected of damaging the unborn child	Reproductive toxicity	Category 2		Warning	P201, P202, P281	P308+P313	P405	P501
H362	May cause harm to breast-fed children	Reproductive toxicity, effects on or via lactation	Additional category	None		P201, P260, P263, P264, P270	P308+P313		
H370	Causes damage to organs	Specific target organ toxicity, single exposure	Category 1		Danger	P260, P264, P270	P307+P311, P321	P405	P501
H371	May cause damage to organs	Specific target organ toxicity, single exposure	Category 2		Warning	P260, P264, P270	P309+P311	P405	P501
H372	Causes damage to organs through prolonged or repeated exposure	Specific target organ toxicity, repeated exposure	Category 1		Danger	P260, P264, P270	P314		P501
H373	Causes damage to organs through prolonged or repeated exposure	Specific target organ toxicity, repeated exposure	Category 2		Warning	P260	P314		P501
H400	Very toxic to aquatic life	Hazardous to the aquatic environment, acute hazard	Category 1		Warning	P273	P391		P501
H401	Toxic to aquatic life	Hazardous to the aquatic	Category 2	None		P273			P501

		environment, acute hazard						
H402	Harmful to aquatic life	Hazardous to the aquatic environment, acute hazard	Category 3	None		P273		P501
H410	Very toxic to aquatic life with long lasting effects	Hazardous to the aquatic environment, long-term hazard	Category 1		Warning	P273	P391	P501
H411	Toxic to aquatic life with long lasting effects	Hazardous to the aquatic environment, long-term hazard	Category 2			P273	P391	P501
H412	Harmful to aquatic life with long lasting effects	Hazardous to the aquatic environment, long-term hazard	Category 3	None		P273		P501
H413	May cause long lasting harmful effects to aquatic life	Hazardous to the aquatic environment, long-term hazard	Category 4	None		P273		P501
H420	Harms public health and the environment by destroying ozone in the upper atmosphere	Hazardous to the ozone layer	Category 1		Warning			P502
Combined H-Codes								
H300+H310	Fatal if swallowed or in contact with skin	Acute toxicity, oral; acute toxicity, dermal	Category 1, 2		Danger			
H300+H330	Fatal if swallowed or if inhaled	Acute toxicity, oral; acute toxicity, inhalation	Category 1, 2		Danger			
H310+H330	Fatal in contact with skin or if inhaled	Acute toxicity, dermal; acute toxicity, inhalation	Category 1, 2		Danger			
H300+H310+H330	Fatal if swallowed, in contact with skin or if inhaled	Acute toxicity, oral; acute toxicity, dermal; acute toxicity, inhalation	Category 1, 2		Danger			
H301+H311	Toxic if swallowed or in contact with skin	Acute toxicity, oral; acute toxicity, dermal	Category 3		Danger			
H301+H331	Toxic if	Acute toxicity,	Category 3		Danger			

	swallowed or if inhaled	oral; acute toxicity, inhalation			
H311+H331	Toxic in contact with skin or if inhaled.	Acute toxicity, dermal; acute toxicity, inhalation	Category 3		Danger
H301+H311+H331	Toxic if swallowed, in contact with skin or if inhaled	Acute toxicity, oral; acute toxicity, dermal; acute toxicity, inhalation	Category 3		Danger
H302+H312	Harmful if swallowed or in contact with skin	Acute toxicity, oral; acute toxicity, dermal	Category 4		Warning
H302+H332	Harmful if swallowed or if inhaled	Acute toxicity, oral; acute toxicity, inhalation	Category 4		Warning
H312+H332	Harmful in contact with skin or if inhaled	Acute toxicity, dermal; acute toxicity, inhalation	Category 4		Warning
H302+H312+H332	Harmful if swallowed, in contact with skin or if inhaled	Acute toxicity, oral; acute toxicity, dermal; acute toxicity, inhalation	Category 4		Warning
H303+H313	May be harmful if swallowed or in contact with skin	Acute toxicity, oral; acute toxicity, dermal	Category 5	None	Warning
H303+H333	May be harmful if swallowed or if inhaled	Acute toxicity, oral; acute toxicity, inhalation	Category 5	None	Warning
H313+H333	May be harmful in contact with skin or if inhaled	Acute toxicity, dermal; acute toxicity, inhalation	Category 5	None	Warning
H303+H313+H333	May be harmful if swallowed, in contact with skin or if inhaled	Acute toxicity, oral; acute toxicity, dermal; acute toxicity, inhalation	Category 5	None	Warning
H315+H320	Cause skin and eye irritation	Skin corrosion/irritation and serious eye damage/eye irritation	Category 2, 2B		Warning

* Div 1.6 - Meets transportation requirements only. For more information, see A Guide to The Globally Harmonized System of Classification and Labeling of Chemicals (GHS).

EU Hazard Statements

EUH001	Explosive when dry
EUH006	Explosive with or without contact with air
EUH014	Reacts violently with water
EUH018	In use may form flammable/explosive vapor-air mixture
EUH019	May form explosive peroxides
EUH029	Contact with water liberates toxic gas
EUH031	Contact with acids liberates toxic gas
EUH032	Contact with acids liberates very toxic gas
EUH044	Risk of explosion if heated under confinement
EUH059	Hazardous to the ozone layer
EUH066	Repeated exposure may cause skin dryness or cracking
EUH070	Toxic by eye contact
EUH071	Corrosive to the respiratory tract

Safe Work Australia Hazard Statements

AUH001	Explosive when dry
AUH006	Explosive with or without contact with air
AUH014	Reacts violently with water
AUH018	In use, may form flammable/explosive vapor/air mixture
AUH019	May form explosive peroxides
AUH029	Contact with water liberates toxic gas
AUH031	Contact with acid liberates toxic gas
AUH032	Contact with acid liberates very toxic gas
AUH044	Risk of explosion if heated under confinement
AUH066	Repeated exposure may cause skin dryness and cracking
AUH070	Toxic by eye contact
AUH071	Corrosive to the respiratory tract

Precautionary Statements

General Precautionary Statements	
P101	If medical advice is needed, have product container or label at hand.
P102	Keep out of reach of children.
P103	Read label before use

Prevention Precautionary Statements	
P201	Obtain special instructions before use.
P202	Do not handle until all safety precautions have been read and understood.
P210	Keep away from heat, hot surface, sparks, open flames and other ignition sources. - No smoking.
P211	Do not spray on an open flame or other ignition source.
P212	Avoid heating under confinement or reduction of the desensitized agent.
P220	Keep away from clothing and other combustible materials.
P221	Take any precaution to avoid mixing with combustibles/...
P222	Do not allow contact with air.
P223	Do not allow contact with water.
P230	Keep wetted with ...
P231	Handle under inert gas.
P232	Protect from moisture.
P233	Keep container tightly closed.
P234	Keep only in original container.
P235	Keep cool.
P240	Ground/bond container and receiving equipment.
P241	Use explosion-proof [electrical/ventilating/lighting/.../] equipment.
P242	Use only non-sparking tools.
P243	Take precautionary measures against static discharge.
P244	Keep valves and fittings free from oil and grease.
P250	Do not subject to grinding/shock/friction/...
P251	Do not pierce or burn, even after use.
P260	Do not breathe dust/fume/gas/mist/vapors/spray.
P261	Avoid breathing dust/fume/gas/mist/vapors/spray.
P262	Do not get in eyes, on skin, or on clothing.
P263	Avoid contact during pregnancy/while nursing.
P264	Wash ... thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P271	Use only outdoors or in a well-ventilated area.
P272	Contaminated work clothing should not be allowed out of the workplace.
P273	Avoid release to the environment.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P281	Use personal protective equipment as required.
P282	Wear cold insulating gloves/face shield/eye protection.
P283	Wear fire resistant or flame retardant clothing.
P284	[In case of inadequate ventilation] Wear respiratory protection.
P285	In case of inadequate ventilation wear respiratory protection.
P231+P232	Handle under inert gas/... Protect from moisture.
P235+P410	Keep cool. Protect from sunlight.

Response Precautionary Statements

P301	IF SWALLOWED:
P302	IF ON SKIN:
P303	IF ON SKIN (or hair):
P304	IF INHALED:
P305	IF IN EYES:
P306	IF ON CLOTHING:
P307	IF exposed:
P308	IF exposed or concerned:
P309	IF exposed or if you feel unwell
P310	Immediately call a POISON CENTER or doctor/physician.
P311	Call a POISON CENTER or doctor/...
P312	Call a POISON CENTER or doctor/... if you feel unwell.
P313	Get medical advice/attention.
P314	Get medical advice/attention if you feel unwell.
P315	Get immediate medical advice/attention.
P320	Specific treatment is urgent (see ... on this label).
P321	Specific treatment (see ... on this label).
P322	Specific measures (see ...on this label).
P330	Rinse mouth.
P331	Do NOT induce vomiting.
P332	IF SKIN irritation occurs:
P333	If skin irritation or rash occurs:
P334	Immerse in cool water [or wrap in wet bandages].
P335	Brush off loose particles from skin.
P336	Thaw frosted parts with lukewarm water. Do not rub affected area.
P337	If eye irritation persists:
P338	Remove contact lenses, if present and easy to do. Continue rinsing.
P340	Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P341	If breathing is difficult, remove victim to fresh air and keep at rest in a position comfortable for breathing.
P342	If experiencing respiratory symptoms:
P350	Gently wash with plenty of soap and water.
P351	Rinse cautiously with water for several minutes.
P352	Wash with plenty of water/...
P353	Rinse skin with water [or shower].
P360	Rinse immediately contaminated clothing and skin with plenty of water before removing clothes.
P361	Take off immediately all contaminated clothing.
P362	Take off contaminated clothing.
P363	Wash contaminated clothing before reuse.
P364	And wash it before reuse.[Added in 2015 version]

P370	In case of fire:
P371	In case of major fire and large quantities:
P372	Explosion risk.
P373	DO NOT fight fire when fire reaches explosives.
P374	Fight fire with normal precautions from a reasonable distance.
P376	Stop leak if safe to do so.
P377	Leaking gas fire: Do not extinguish, unless leak can be stopped safely.
P378	Use ... to extinguish.
P380	Evacuate area.
P381	In case of leakage, eliminate all ignition sources.
P390	Absorb spillage to prevent material damage.
P391	Collect spillage.
P301+P310	IF SWALLOWED: Immediately call a POISON CENTER/doctor/...
P301+P312	IF SWALLOWED: call a POISON CENTER/doctor/... IF you feel unwell.
P301+P330+P331	IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P302+P334	IF ON SKIN: Immerse in cool water [or wrap in wet bandages].
P302+P335+P334	Brush off loose particles from skin. Immerse in cool water [or wrap in wet bandages].
P302+P350	IF ON SKIN: Gently wash with plenty of soap and water.
P302+P352	IF ON SKIN: wash with plenty of water.
P303+P361+P353	IF ON SKIN (or hair): Take off Immediately all contaminated clothing. Rinse SKIN with water [or shower].
P304+P312	IF INHALED: Call a POISON CENTER/doctor/... if you feel unwell.
P304+P340	IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P304+P341	IF INHALED: If breathing is difficult, remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do - continue rinsing.
P306+P360	IF ON CLOTHING: Rinse Immediately contaminated CLOTHING and SKIN with plenty of water before removing clothes.
P307+P311	IF exposed: call a POISON CENTER or doctor/physician.
P308+P311	IF exposed or concerned: Call a POISON CENTER/doctor/...
P308+P313	IF exposed or concerned: Get medical advice/attention.
P309+P311	IF exposed or if you feel unwell: call a POISON CENTER or doctor/physician.
P332+P313	IF SKIN irritation occurs: Get medical advice/attention.
P333+P313	IF SKIN irritation or rash occurs: Get medical advice/attention.
P335+P334	Brush off loose particles from skin. Immerse in cool water/wrap in wet bandages.
P337+P313	IF eye irritation persists: Get medical advice/attention.
P342+P311	IF experiencing respiratory symptoms: Call a POISON CENTER/doctor/...
P361+P364	Take off immediately all contaminated clothing and wash it before reuse.
P362+P364	Take off contaminated clothing and wash it before reuse.
P370+P376	in case of fire: Stop leak if safe to do so.
P370+P378	In case of fire: Use ... to extinguish.
P370+P380	In case of fire: Evacuate area.

P370+P380+P375	In case of fire: Evacuate area. Fight fire remotely due to the risk of explosion.
P371+P380+P375	In case of major fire and large quantities: Evacuate area. Fight fire remotely due to the risk of explosion.

Storage Precautionary Statements

P401	Store in accordance with ...
P402	Store in a dry place.
P403	Store in a well-ventilated place.
P404	Store in a closed container.
P405	Store locked up.
P406	Store in corrosive resistant/... container with a resistant inner liner.
P407	Maintain air gap between stacks or pallets.
P410	Protect from sunlight.
P411	Store at temperatures not exceeding ... °C/...°F.
P412	Do not expose to temperatures exceeding 50 °C/ 122 °F.
P413	Store bulk masses greater than ... kg/...lbs at temperatures not exceeding ... °C/...°F.
P420	Store separately.
P422	Store contents under ...
P402+P404	Store in a dry place. Store in a closed container.
P403+P233	Store in a well-ventilated place. Keep container tightly closed.
P403+P235	Store in a well-ventilated place. Keep cool.
P410+P403	Protect from sunlight. Store in a well-ventilated place.
P410+P412	Protect from sunlight. Do not expose to temperatures exceeding 50 °C/122°F.
P411+P235	Store at temperatures not exceeding ... °C/...°F. Keep cool.

Disposal Precautionary Statements

P501	Dispose of contents/container to ...
P502	Refer to manufacturer or supplier for information on recovery or recycling

COMBINED LIST of Particularly Hazardous Substances

revised 2/4/2021

list compiled by Hector Acuna, UCSB

IARC list 1 are Carcinogenic to humans
IARC list Group 2A Probably carcinogenic to humans
IARC list Group 2B Possibly carcinogenic to humans
Prop 65 known to cause cancer or reproductive toxicity
KNOWN Carcinogens from National Toxicology Program (NTP)
Reasonably Anticipated NTP
EPA Haz list

If any of the chemicals listed below are used in your research then complete a Standard Operating Procedure (SOP) for the product as described in the Chemical Hygiene Plan.

Material(s) not on the list does not preclude one from completing an SOP. Other extremely toxic chemicals or other high hazards will require the development of an SOP.

Red= added in 2020 or status change

COMBINED LIST of Particularly Hazardous Substances	CAS	Source from where the material is listed.		
6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10- hexachloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide		Acutely Toxic		
Methanimidamide, N,N-dimethyl-N'-[2-methyl-4-[[(methylamino)carbonyl]oxy]phenyl]-		Acutely Toxic		
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (Methyl-CCNU)		Prop 65	KNOWN Carcinogens NTP	
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU)		IARC list Group 2A	Reasonably Anticipated NTP	
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU) (Lomustine)		Prop 65		
1-(o-Chlorophenyl)thiourea		Acutely Toxic		
1,1,1,2-Tetrachloroethane		IARC list Group 2B		
1,1,2,2-Tetrachloroethane		Prop 65	IARC list Group 2B	
1,1-Dichloro-2,2-bis(*p* -chloropheny)ethylene (DDE)		Prop 65		
1,1-Dichloroethane		Prop 65		
1,1-Dimethylhydrazine		IARC list Group 2B	Reasonably Anticipated NT	Prop 65
1,2,3-Propanetriol, trinitrate		Acutely Toxic		
1,2,3-Trichloropropane		IARC list Group 2A	Reasonably Anticipated NT	Prop 65
1,2-Benzenediol, 4-[1-hydroxy-2-(methylamino)ethyl]-,		Acutely Toxic		
1,2-Dibromo-3-chloropropane		IARC list Group 2B	Reasonably Anticipated NT	Prop 65
1,2-Dibromoethane (Ethylene Dibromide)		Reasonably Anticipated NTP		
1,2-Dichloroethane		IARC list 2B	Reasonably Anticipated NTP	
1,2-Dichloropropane		IARC list 1	Prop 65	
1,2-Diethylhydrazine		IARC list2B	Prop 65	
1,2-Dimethylhydrazine		IARC list 2A	Prop 65	
1,2-Epoxybutane		IARC list 2B		
1,2-Propylenimine		Acutely Toxic		
1,3-Butadiene		IARC list 1	KNOWN Carcinogens NTP	Prop 65
1,3-Dichloro-2-propanol		IARC list Group 2B		
1,3-Dichloro-2-propanol (1,3-DCP)		Prop 65		
1,3-Dichloropropene		Prop 65	Reasonably Anticipated NT	IARC list 2B
1,3-dinitropyrene		Prop 65		
1,3-Dithiolane-2-carboxaldehyde, 2,4-dimethyl-, O- [(methylamino)-carbonyl]oxime.		Acutely Toxic		
1,3-Propane sultone		IARC list 2A	Reasonably Anticipated NT	Prop 65
1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa- chloro-1,4,4a,5,8,8a,-hexahydro-,(1alpha,4alpha,4abeta,5alpha,8alpha,8 abeta)-		Acutely Toxic		
1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa- chloro-1,4,4a,5,8,8a-hexahydro-,(1alpha,4alpha,4abeta,5beta,8beta,8ab eta)-		Acutely Toxic		
1,4-Butanediol dimethanesulfonate (Busulfan) or (Myleran®)		Prop 65	KNOWN Carcinogens NTP	
1,4-Dichloro-2-butene		Prop 65		
1,4-Dichloro-2-nitrobenzene	611-06-3	IARC list 2B	Prop 65	

1,4-Dichlorobenzene		Reasonably Anticipated NTP		
1,4-Dioxane		IARC list 2B	Reasonably Anticipated NT	Prop 65
1,6-Dinitropyrene		IARC list 2B	Reasonably Anticipated NT	Prop 65
1,8-Dinitropyrene		IARC list 2B	Reasonably Anticipated NT	Prop 65
1-[(5-Nitrofurfurylidene)amino]-2-imidazolidinone		IARC list 2B	Prop 65	
1-Acetyl-2-thiourea		Acutely Toxic		
1-Amino-2,4-dibromoanthraquinone		IARC list Group 2B	Reasonably Anticipated NT	Prop 65
1-Amino-2-methylanthraquinone		Reasonably Anticipated	Prop 65	
1-Bromopropane	106-94-5	Prop 65	Reasonably Anticipated NT	IARC list 2B
1-Bromo-3-chloropropane	109-70-6	IARC list 2B		
1-Butyl glycidyl ether	2426-08-6	IARC list 2B		
1-Chloro-2-methylpropene		IARC list 2B		
1-Chloro-4-nitrobenzene		Prop 65	EPA Haz list	
1-Hydroxyanthraquinone		IARC list 2B	Prop 65	
1-Naphthylamine		Prop 65		
1-Nitropyrene		IARC list 2A	Reasonably Anticipated NT	Prop 65
1-tert-Butoxypropan-2-ol	57018-52-7	IARC list 2B		
2-(2-Formylhydrazino)-4-(5-nitro-2-furyl)thiazole		IARC list 2B	Prop 65	
2,2-bis-(Bromoethyl)-1,3-propanediol (Technical Grade)		Reasonably Anticipated NTP		
2,2-Bis(bromomethyl)-1,3-propanediol		Prop 65		
2,2-Bis(bromomethyl)propane-1,3-diol		IARC list 2B		
2,3,4,7,8-Pentachlorodibenzofuran		IARC list 1		
2,3,7,8-Tetrachlorodibenzo-para-dioxin		IARC list 1		
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD); “Dioxin”		KNOWN Carcinogens N	Prop 65	
2,3-Dibromo-1-propanol		Reasonably Anticipated	Prop 65	
2,3-Dibromopropan-1-ol		IARC list 2B		
2,4,5-Trimethylaniline and its strong acid salts		Prop 65		
2,4,6-Trichlorophenol	88-06-2	IARC list 2B	Reasonably Anticipated NT	Prop 65
2,4.6-Trinitrotoluene (TNT)		Prop 65		
2,4-Diaminoanisole		IARC list 2B	Prop 65	
2,4-Diaminoanisole Sulfate		Reasonably Anticipated	Prop 65	
2,4-Diamino-6-chloro-s -triazine (DACT)		Prop 65		
2,4-Diaminotoluene		IARC list 2B	Reasonably Anticipated NT	Prop 65
2,4-Dichloro-1-nitrobenzene	611-06-3	Prop 65	IARC list 2B	
2,4-Dinitroaniline		EPA Haz list		
2,4-Dinitrophenol		Acutely Toxic		
2,4-Dinitrotoluene		IARC list 2B	Prop 65	
2,4-Hexadienal		IARC list Group 2B	Prop 65	
2,4-Hexadienal (89% trans, trans isomer; 11% cis, trans isomer)		Prop 65		
2,5-Hexanedione		Prop 65		
2,6-Dimethylaniline (2,6-Xylidine)		IARC list 2B		
2,6-Dimethyl-N-nitrosomorpholine (DMNM)		Prop 65	EPA Haz list	
2,6-Dinitrotoluene		IARC list 2B	Prop 65	
2,6-Dinitrotoluene		IARC list Group 2A		
2,6-Xylidine (2,6-Dimethylaniline)		Prop 65		
2-Acetylaminofluorene		Reasonably Anticipated	Prop 65	
2-Amino-1-methyl-6-phenylimidazo[4,5-b]pyridine (PhIP)		Reasonably Anticipated NTP		

2-Amino-3,4-dimethylimidazo[4,5-f]quinoline (MeIQ)		Reasonably Anticipated NTP		
2-Amino-3,8-dimethylimidazo[4,5-f]quinoxaline (MeIQx)		Reasonably Anticipated NTP		
2-Amino-3-methylimidazo[4,5-f]quinoline (IQ)		Reasonably Anticipated NTP		
2-Amino-4-chlorophenol	95-85-2	Prop 65	IARC list 2B	
2-Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole		IARC list 2B	Prop 65	
2-Aminoanthraquinone		Reasonably Anticipated	Prop 65	
2-Aminofluorene		Prop 65		
2-Bromopropane		Prop 65		
2-Butanone, 3,3-dimethyl-1(methylthio)-, O-[methylamino)carbonyl] oxime		Acutely Toxic		
2-Chloropropionic acid		Prop 65		
2-Chloronitrobenzene	88-73-3	Prop 65	IARC list 2B	
2-Cyclohexyl-4,6-dinitrophenol		Acutely Toxic		
2H-1-Benzopyran-2-one, 4-hydroxy-3-(3- oxo-1-phenylbutyl)-, & salts, when present at concentrations greater than 0.3%		Acutely Toxic		
2-Mercaptobenzothiazole	149-30-4	IARC list 2A		
2-Methyl-1-nitroanthraquinone (uncertain purity)		IARC list 2B	Prop 65	
2-Methylaziridine (Propyleneimine)		IARC list 2B	Reasonably Anticipated NT	Prop 65
2-methylimidazole		Prop 65		
2-Methylimidazole		IARC list Group 2B		
2-Methyllactonitrile		Acutely Toxic		
2-Naphthylamine		KNOWN Carcinogens N	IARC list Group 1	Prop 65
2-Nitroanisole		IARC list 2B		
2-Nitrofluorene		IARC list 2B	Prop 65	
2-Nitropropane		IARC list 2B	Reasonably Anticipated NT	Prop 65
2-Nitrotoluene		IARC list 2A		
2-Propanone, 1-bromo-		Acutely Toxic		
2-Propen-1-ol		Acutely Toxic		
2-Propenal		Acutely Toxic		
2-Propyn-1-ol		Acutely Toxic		
3(2H)-Isoxazolone, 5-(aminomethyl)-		Acutely Toxic		
3-(N-Nitrosomethylamino)propionitrile		IARC list 2B	Prop 65	
3,3',4,4' Tetrachloroazobenzene	14047-09-7	IARC list 2A	Prop 65	
3,3´-Dichlorobenzidine and 3,3´-Dichlorobenzidine Dihydrochloride		Reasonably Anticipated NTP		
3,3´-Dimethoxybenzidine (See 3,3´-Dimethoxybenzidine and Dyes Metabolized to 3,3´-Dimethoxybenzidine)		Reasonably Anticipated NTP		
3,3´-Dimethylbenzidine (See 3,3´-Dimethylbenzidine and Dyes Metabolized to 3,3´-Dimethylbenzidine)		Reasonably Anticipated NTP		
3,3'-Dichloro-4,4'-diaminodiphenyl ether		IARC list 2B	Prop 65	
3,3'-Dichlorobenzidine		IARC list 2B	Prop 65	
3,3'-Dichlorobenzidine dihydrochloride		Prop 65		
3,3'-Dimethoxybenzidine (ortho-Dianisidine)		IARC list 2B	Prop 65	
3,3'-Dimethoxybenzidine dihydrochloride		Prop 65		
3,3'-Dimethoxybenzidine-based dyes metabolized to 3,3'-dimethoxybenzidine		Prop 65		
3,3'-Dimethylbenzidine (ortho-Tolidine)		IARC list 2B	Prop 65	
3,3'-Dimethylbenzidine dihydrochloride		Prop 65		
3,3'-Dimethylbenzidine-based dyes metabolized to 3,3'-dimethylbenzidine		Prop 65		
3,4,5,3',4'-Pentachlorobiphenyl (PCB-126)		IARC list 1		
3,7-Dinitrofluoranthene		IARC list 2B	Prop 65	
3,9-Dinitrofluoranthene		IARC list 2B	Prop 65	
3-Amino-9-ethylcarbazole hydrochloride		Prop 65		

3-Chloro-2-methylpropene technical grade	563-47-3	Reasonably Anticipated	Prop 65	IARC list 2B
3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone		IARC list 2B		
3-Chloropropionitrile		Acutely Toxic		
3-Isopropylphenyl N-methylcarbamate.		Acutely Toxic		
3-Methylcholanthrene		Prop 65		
3-Monochloro-1,2-propanediol		IARC list Group 2B		
3-Monochloropropane-1,2-diol (3-MCDP)		Prop 65		
3-Nitrobenzanthrone		IARC list Group 2B		
4-(N-Nitrosomethylamino)-1-(3-pyridyl)-1-butanone		Reasonably Anticipated	Prop 65	
4,4´-Methylenebis(2-chloroaniline)		Reasonably Anticipated NTP		
4,4´-Methylenedianiline and Its Dihydrochloride Salt		Reasonably Anticipated NTP		
4,4´-Oxydianiline		Reasonably Anticipated NTP		
4,4´-Thiodianaline		Reasonably Anticipated NTP		
4,4'-Diaminodiphenyl ether		IARC list 2B	Prop 65	
4,4'-Methylene bis(2-chloroaniline)		Prop 65		
4,4'-Methylene bis(2-methylaniline)		IARC list 2B	Prop 65	
4,4'-Methylene bis(N,N-dimethyl)benzenamine		Prop 65		
4,4'-Methylenebis(2-chloroaniline) (MOCA)		IARC list 1		
4,4'-Methylenedianiline		IARC list 2B	Prop 65	
4,4'-Methylenedianiline dihydrochloride		Prop 65		
4,4'-Thiodianiline		IARC list 2B	Prop 65	
4,6-Dinitro-o-cresol, & salts		Acutely Toxic		
4,7,7a-tetrahydro-4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a		Acutely Toxic		
4-4´-Methylenebis(N,N-dimethyl)benzenamine		Reasonably Anticipated NTP		
4-Amino-2-nitrophenol		Prop 65		
4-Aminobiphenyl		IARC list 1		
4-Aminobiphenyl		KNOWN Carcinogens N	IARC list Group 1	Prop 65
4-Aminopyridine		Acutely Toxic		
4-Chlorobenzotrifluoride	98-56-6	IARC list 2B		
4-Chloronitrobenzene	100-00-5	IARC list 2B		
4-Chloro-ortho-phenylenediamine		IARC list 2B	Prop 65	Reasonably Anticipated NTP
4-Chloro-ortho-toluidine		IARC list 2A		
4-Dimethylaminoazobenzene		Reasonably Anticipated	Prop 65	
4-methylimidazole		Prop 65		
4-Methylimidazole		IARC list Group 2B		
4-Nitrobiphenyl		Prop 65		
4-Nitropyrene		IARC list 2B	Prop 65	Reasonably Anticipated NTP
4-Pyridinamine		Acutely Toxic		
4-Vinyl-1-cyclohexene Diepoxide (Vinyl cyclohexenedioxide)		Reasonably Anticipated	Prop 65	
4-Vinylcyclohexene		IARC list 2B	Prop 65	
4-Vinylcyclohexene diepoxide		IARC list 2B		
5-(Aminomethyl)-3-isoxazolol		Acutely Toxic		
5-(Morpholinomethyl)-3-[(5-nitrofurfurylidene)amino]-2-oxazolidinone		IARC list 2B	Prop 65	
5-Chloro-*o*-toluidine and its strong acid salts		Prop 65		
5-Methoxypsoralen		IARC list 2A	Prop 65	
5-Methylchrysene		IARC list 2B	Prop 65	Reasonably Anticipated NTP
5-Nitroacenaphthene		IARC list 2B	Prop 65	

6-Nitrochrysene		IARC list 2A	Prop 65	Reasonably Anticipated NTP	
7,12-Dimethylbenz(a)anthracene		Prop 65			
7-Benzofuranol, 2,3-dihydro-2,2-dimethyl-, methylcarbamate.		Acutely Toxic			
7H-Dibenzo[c,g]carbazole		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
7H-Dibenzo[c,g]carbazole		IARC list Group 2B			
7-Oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid		Acutely Toxic			
8-Methoxypsoralen with ultraviolet A therapy		Prop 65			
α-Methylstyrene		IARC list Group 2B			
A-alpha-C (2-Amino-9H-pyrido[2,3-b]indole)		IARC list 2B	Prop 65		
Abiraterone acetate		Prop 65			
Acetaldehyde		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Acetaldehyde associated with consumption of alcoholic		IARC list 1			
Acetaldehyde, chloro-		Acutely Toxic			
Acetamide		IARC list 2B	Prop 65		
Acetamide, 2-fluoro-		Acutely Toxic			
Acetamide, N-(aminothioxomethyl)-		Acutely Toxic			
Acetazolamide		Prop 65			
Acetic acid, fluoro-, sodium salt		Acutely Toxic			
Acetochlor		Prop 65			
Acetohydroxamic acid		Prop 65			
Acetone Cyanohydrin		EPA Haz list			
Acetone Thiosemicarbazide		EPA Haz list			
Acid mists, strong inorganic		IARC list 1			
Acifluorfen sodium		Prop 65			
Acheson process, occupational exposure associated with		IARC list 1			
Acrolein		EPA Haz list			
Acrylamide		IARC list 2A	Reasonably Anticipated NT	Prop 65	EPA Haz list
Acrylonitrile		IARC list 2B	Reasonably Anticipated NT	Prop 65	EPA Haz list
Acrylyl Chloride		EPA Haz list			
Actinomycin D		Prop 65			
Adiponitrile		EPA Haz list			
Adriamycin (Doxorubicin Hydrochloride)		IARC list 2A	Reasonably Anticipated NTP		
AF-2 [2-(2-Furyl)-3-(5-nitro-2-furyl)acrylamide]		IARC list 2B	Prop 65		
Aflatoxins		KNOWN Carcinogens N	IARC list Group 1	Prop 65	
Alachlor		Prop 65			
Alcoholic beverages		IARC list 1	KNOWN Carcinogens NTP	Prop 65	
Aldicarb		EPA Haz list			
Aldicarb sulfone		Acutely Toxic			
Aldrin		Prop 65	EPA Haz list		
All-trans retinoic acid		Prop 65			
Allyl Alcohol		EPA Haz list			
Allylamine		EPA Haz list			
Aloe vera , whole leaf extract		IARC list 2B	Prop 65		
alpha,alpha-Dimethylphenethylamine		Acutely Toxic			
alpha-Chlorinated toluenes (benzal chloride, benzotrichloride, benzyl chloride) and benzoyl chloride		IARC list 2A			
alpha-Methyl styrene		Prop 65			
alpha-Naphthylthiourea		Acutely Toxic			

Alprazolam		Prop 65		
Altretamine		Prop 65		
Aluminium production		IARC list 1		
Aluminum Phosphide		EPA Haz list		
Amantadine hydrochloride		Prop 65		
a-methyl styrene		Prop 65		
Amikacin sulfate		Prop 65		
Aminoglutethimide		Prop 65		
Aminoglycosides		Prop 65		
Aminopterin		Prop 65	EPA Haz list	
Amiodarone hydrochloride		Prop 65		
Amiton		EPA Haz list		
Amiton Oxalate		EPA Haz list		
Amitraz		Prop 65		
Amitrole		Reasonably Anticipated	Prop 65	
Ammonia		EPA Haz list		
Ammonium picrate		Acutely Toxic		
Ammonium vanadate		Acutely Toxic		
Amoxapine		Prop 65		
Amphetamine		EPA Haz list		
Amsacrine		IARC list 2B	Prop 65	
Anabolic steroids		Prop 65		
Analgesic Mixtures Containing Phenacetin (See Phenacetin and Analgesic Mixtures Containing Phenacetin)		KNOWN Carcinogens N	Prop 65	
Androgenic (anabolic) steroids		IARC list 2A		
Androstenedione		Prop 65		
Angiotensin converting enzyme (ACE) inhibitors		Prop 65		
Aniline		Prop 65	EPA Haz list	
Aniline hydrochloride		Prop 65		
Aniline, 2,4,6-Trimethyl-		EPA Haz list		
Anisindione		Prop 65		
Anthraquinone		Prop 65		
Anthraquinone		IARC list Group 2B		
Antimony oxide (Antimony trioxide)		Prop 65		
Antimony Pentafluoride		EPA Haz list		
Antimony trioxide		IARC list 2B		
Antimycin A		EPA Haz list		
ANTU		EPA Haz list		
Aramite®		IARC list 2B	Prop 65	
Areca nut		IARC list 1	Prop 65	
Argentate(1-), bis(cyano-C)-,potassium		Acutely Toxic		
Aristolochic acid		IARC list 1	Prop 65	KNOWN Carcinogens NTP
Aristolochic acid, plants containing		IARC list 1		
Arsenic (inorganic oxides)		Prop 65		
Arsenic acid		Acutely Toxic		
Arsenic Compounds, Inorganic		KNOWN Carcinogens N	IARC list Group 1	Prop 65
Arsenic oxide		Acutely Toxic		
Arsenic Pentoxide		EPA Haz list		

Arsenic trioxide		Acutely Toxic		
Arsenous Oxide		EPA Haz list		
Arsenous Trichloride		EPA Haz list		
Arsine		EPA Haz list		
Arsine, diethyl		Acutely Toxic		
Arsonous dichloride, phenyl-		Acutely Toxic		
Asbestos		KNOWN Carcinogens N	IARC list Group 1	Prop 65
Atenolol		Prop 65		
Atrazine		Prop 65		
Auramine		IARC list 2B	Prop 65	
Auramine production		IARC list 1		
Auranofin		Prop 65		
Avermectin B1 (Abamectin		Prop 65		
Azacitidine		IARC list 2A	Reasonably Anticipated NT	Prop 65
Azaserine		IARC list 2B	Prop 65	
Azathioprine		IARC list 1	KNOWN Carcinogens NTP	Prop 65
Azinphos-Ethyl		EPA Haz list		
Azinphos-Methyl		EPA Haz list		
Aziridine		IARC list 2B	Acutely Toxic	
Aziridine, 2-methyl-		Acutely Toxic		
Azobenzene		Prop 65		
Barbiturates		Prop 65		
Barium cyanide		Acutely Toxic		
Basic Red 9 Monohydrochloride (basic fuchsin dye)		Reasonably Anticipated NTP		
Beclomethasone dipropionate		Prop 65		
Benomyl		Prop 65		
Benthiavalicarb-isopropyl		Prop 65		
Benz[a]anthracene		IARC list 2B	Reasonably Anticipated NT	Prop 65
Benz[j]aceanthrylene		IARC list 2B		
Benzal Chloride		EPA Haz list		
Benzenamine, 3-(Trifluoromethyl)-		EPA Haz list		
Benzenamine, 4-chloro-		Acutely Toxic		
Benzenamine, 4-nitro-		Acutely Toxic		
Benzene		IARC list 1	KNOWN Carcinogens NTP	Prop 65
Benzene, (chloromethyl)-		Acutely Toxic		
Benzene, 1-(Chloromethyl)-4-Nitro-		EPA Haz list		
Benzenearsonic Acid		EPA Haz list		
Benzeneethanamine, alpha,alpha- dimethyl-		Acutely Toxic		
Benzenethiol		Acutely Toxic		
Benzidine		IARC list 1	KNOWN Carcinogens NTP	Prop 65
Benzidine, dyes metabolized to		IARC list 1		
Benzidine-based dyes		Prop 65		
Benzimidazole, 4,5-Dichloro-2-(Trifluoromethyl)-		EPA Haz list		
Benzo[a]pyrene		IARC list 1	Reasonably Anticipated NT	Prop 65
Benzo[b]fluoranthene		IARC list 2B	Reasonably Anticipated NT	Prop 65
Benzo[c]phenanthrene		IARC list 2B		
Benzo[j]fluoranthene		IARC list 2B	Reasonably Anticipated NT	Prop 65

Benzo[k]fluoranthene		IARC list 2B	Reasonably Anticipated NT	Prop 65	
Benzodiazepines		Prop 65			
Benzofuran		IARC list 2B	Prop 65		
Benzoic acid, 2-hydroxy-, compd. With (3aS-cis)-1,2,3,3a,8,8a-hexahydro-1,3a,8-trimethylpyrrolo[2,3-b]indol-5-yl methylcarbamate ester (1:1)		Acutely Toxic			
benzophenone		Prop 65			
Benzophenone		IARC list Group 2B			
Benzotrichloride		Reasonably Anticipated	Prop 65	EPA Haz list	
Benzphetamine hydrochloride		Prop 65			
Benzyl chloride		Prop 65	EPA Haz list	Acutely Toxic	
Benzyl Cyanide		EPA Haz list			
Benzyl violet		IARC list 2B	Prop 65		
Beryllium and beryllium compounds		IARC list 1	KNOWN Carcinogens NTP	Prop 65	
Beryllium oxide		Prop 65			
Beryllium powder		Acutely Toxic			
Beryllium sulfate		Prop 65			
beta-Butyrolactone		IARC list 2B	Prop 65		
beta-Propiolactone		IARC list 2B	Prop 65	Reasonably Antic	Acutely Toxic
beta-Myrcene	123-35-3	IARC list 2B	Prop 65		
Betel quid with tobacco		IARC list 1	Prop 65		
Betel quid without tobacco		IARC list 1	Prop 65		
Bevacizumab	216974-75-3	Prop 65			
Bicyclo[2.2.1]Heptane-2-Carbonitrile, 5-Chloro-6-((((Methylamino)Carbonyl)Oxy)Imino)-, (1s-(1-alpha,2-beta,4-alpha,5-alpha,6E))-		EPA Haz list			
Biomass fuel (primarily wood), indoor emissions from household combustion of		IARC list 2B			
Bis(2-chloro-1-methylethyl)ether, technical grade		Prop 65			
Bis(2-chloroethyl)ether		Prop 65			
bis(Chloroethyl) nitrosourea		Reasonably Anticipated NTP			
Bis(Chloromethyl) Ketone		EPA Haz list			
Bis(chloromethyl)ether; chloromethyl methyl ether		IARC list 1	KNOWN Carcinogens NTP	Prop 65	
Bischloroethyl nitrosourea (BCNU)		IARC list 2A	Prop 65		
Bisphenol A (BPA)	80-05-7	Prop 65			
Bitoscanate		EPA Haz list			
Bitumens, extracts of steam-refined and air-refined		IARC list 2B	Prop 65		
Bitumens, occupational exposure to hard bitumens and their emissions during mastic asphalt work		IARC list Group 2B			
Bitumens, occupational exposure to oxidized bitumens and their emssions during roofing		IARC list Group 2A			
Bitumens, occupational exposure to straight-run bitumens and their emissions during road paving		IARC list Group 2B			
BK polyomavirus (BKV)		IARC list Group 2B			
Bleomycins		IARC list 2B			
Boron Trichloride		EPA Haz list			
Boron Trifluoride		EPA Haz list			
Boron Trifluoride Compound With Methyl Ether (1:1)		EPA Haz list			
Bracken fern		IARC list 2B	Prop 65		
Bromacil lithium salt		Prop 65			
Bromadiolone		EPA Haz list			
Bromate		Prop 65			
Bromine		EPA Haz list			
Bromoacetone		Acutely Toxic			
Bromodichloroacetic acid		Prop 65			

Bromochloroacetic acid		IARC list Group 2B			
Bromodichloromethane		Prop 65			
Bromodichloromethane		IARC list 2B	Reasonably Anticipated NTP		
Bromoethane		Prop 65			
Bromoform		Prop 65			
Bromoxynil		Prop 65			
Bromoxynil octanoate		Prop 65			
1-Bromopropane (1-BP)		Prop 65			
Brucine		Acutely Toxic			
Busulfan		IARC list 1			
Butabarbital sodium		Prop 65			
Butyl benzyl phthalate (BBP)		Prop 65			
Butylated hydroxyanisole		Prop 65			
Butylated hydroxyanisole (BHA)		IARC list 2B	Reasonably Anticipated NTP		
C.I. Acid Red 114		Prop 65			
C.I. Basic Red 9 Monohydrochloride		Reasonably Anticipated	Prop 65		
C.I. Direct Blue 15		Prop 65			
C.I. Direct Blue 218		Prop 65			
C.I. Solvent Yellow 14		Prop 65			
Cacodylic acid		Prop 65			
Cadmium and Cadmium Compounds		KNOWN Carcinogens N	IARC list 1	Prop 65	
Cadmium Oxide		EPA Haz list			
Cadmium Stearate		EPA Haz list			
Caffeic acid		IARC list 2B	Prop 65		
Calcium Arsenate		EPA Haz list			
Calcium cyanide		Acutely Toxic			
Camphechlor		EPA Haz list			
Cannabis (marijuana) smoke		Prop 65			
Cantharidin		EPA Haz list			
Captafol		IARC list 2A	Prop 65	Reasonably Anticipated NTP	
Captan		Prop 65			
Carbachol Chloride		EPA Haz list			
Carbamazepine		Prop 65			
Carbamic acid, [(dibutylamino)- thio]methyl-, 2,3-dihydro-2,2- dimethyl- 7-benzofuranyl ester.		Acutely Toxic			
Carbamic acid, dimethyl-, 1-[(dimethyl- amino)carbonyl]- 5-methyl-1H- pyrazol-3-yl ester.		Acutely Toxic			
Carbamic acid, dimethyl-, 3-methyl-1-(1-methylethyl)-1H- pyrazol-5-yl ester.		Acutely Toxic			
Carbamic acid, methyl-, 3-methylphenyl ester.		Acutely Toxic			
Carbamic Acid, Methyl-, O-(((2,4-Dimethyl-1, 3-Dithiolan-2-yl)Methylene)Amino)-		EPA Haz list			
Carbaryl		Prop 65			
Carbazole		Prop 65			
Carbazole		IARC list Group 2B			
Carbofuran		EPA Haz list	Acutely Toxic		
Carbon black (airborne, unbound particles of respirable size)		IARC list 2B	Prop 65		
Carbon Disulfide		EPA Haz list	Prop 65	Acutely Toxic	
Carbon electrode manufacture		IARC list 2A			
Carbon monoxide		Prop 65			
Carbon nanotubes, multi-walled MWCNT-7	308068-56-6	IARC list 2B			

Carbon tetrachloride		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Carbon-black extracts		Prop 65			
Carbonic dichloride		Acutely Toxic			
Carbophenothion		EPA Haz list			
Carboplatin		Prop 65			
Carbosulfan		Acutely Toxic			
Carrageenan, degraded (Poligeenan)		IARC list 2B			
Catechol		IARC list 2B	Prop 65		
Ceramic Fibers (Respirable Size)		Reasonably Anticipated	Prop 65		
Certain combined chemotherapy for lymphomas		Prop 65			
Chenodiol		Prop 65			
Chlomaphazine		IARC list 1			
Chloral		IARC list 2A	Prop 65		
Chloral Hydrate		IARC list 2A	Prop 65		
Chlorambucil		KNOWN Carcinogens N	Prop 65	IARC list 1	
Chloramphenicol		IARC list 2A	Reasonably Anticipated NTP		
Chlorcyclizine hydrochloride		Prop 65			
Chlordane		IARC list 2B	Prop 65	EPA Haz list	
Chlordecone (Kepone)		IARC list 2B	Prop 65		
Chlordiazepoxide		Prop 65			
Chlordiazepoxide hydrochloride		Prop 65			
Chlordimeform		Prop 65			
Chlorendic acid		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Chlorfenvinfos		EPA Haz list			
Chlorinated Paraffins (Chlorinated paraffins C12 and average degree of chlorination approximately 60%)		Reasonably Anticipated	Prop 65	IARC list 2B	
Chlorine		EPA Haz list			
Chlormephos		EPA Haz list			
Chlormequat Chloride		EPA Haz list			
Chlornaphazine		IARC list 1			
Chlorpyrifos	2921-88-2	Prop 65			
Chloroacetaldehyde		Acutely Toxic			
Chloroacetic Acid		EPA Haz list			
Chloroethane (Ethyl chloride)		Prop 65			
Chloroethanol		EPA Haz list			
Chloroethyl Chloroformate		EPA Haz list			
Chloroform		IARC list 2B	Prop 65	Reasonably Antic	EPA Haz list
Chloromethyl Ether		EPA Haz list			
Chloromethyl methyl ether (technical grade)		Prop 65	EPA Haz list	KNOWN Carcinogens NTP	
Chlorophacinone		EPA Haz list			
Chlorophenoxy herbicides or 2,4-D (2,4-dichlorophenoxyacetic acid)	94-75-7	IARC list 2B			
Chloroprene		Reasonably Anticipated	Prop 65	IARC list 2B	
Chlorothalonil		IARC list 2B	Prop 65		
Chlorotrianisene		Prop 65			
Chloroxuron		EPA Haz list			
Chlorozotocin		IARC list 2A	Prop 65	Reasonably Anticipated NTP	
Chlorthiophos		EPA Haz list			
Chromic Chloride		EPA Haz list			

Chromium Hexavalent Compounds		KNOWN Carcinogens N	Prop 65	IARC list 1	
Chrysene		IARC list 2B	Prop 65		
CI Acid Red 114		IARC list 2B			
CI Basic Red 9		IARC list 2B			
CI Direct Blue		IARC list 2B			
C.I. Disperse Yellow 3		Prop 65	EPA Haz list		
Ciclosporin (Cyclosporin A; Cyclosporine)		Prop 65			
Cidofovir		Prop 65			
Cinnamyl anthranilate		Prop 65			
Cisplatin		IARC list 2A	Prop 65	Reasonably Anticipated NTP	
Citrus Red No. 2		IARC list 2B	Prop 65		
Cladribine		Prop 65			
Clarithromycin		Prop 65			
Clobetasol propionate		Prop 65			
Clofibrate		Prop 65			
Clomiphene citrate		Prop 65			
Clonorchis sinensis (infection with)		IARC list 1			
Clorazepate dipotassium		Prop 65			
CMNP (pyrazachlor)		Prop 65			
Coal gasification		IARC list 1			
Coal Tar Pitches (See Coal Tars and Coal Tar Pitches)		KNOWN Carcinogens N	IARC list 1		
Coal Tars (See Coal Tars and Coal Tar Pitches)		KNOWN Carcinogens NTP			
Coal-tar distillation		IARC list 1			
Cobalt and cobalt compounds		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Cobalt Carbonyl		EPA Haz list			
Cobalt metal powder		Prop 65	Reasonably Anticipated NTP		
Cobalt metal with tungsten carbide		IARC list 2A	Reasonably Anticipated NTP		
Cobalt metal without tungsten carbide		IARC list 2B			
Cobalt Sulfate		Reasonably Anticipated	Prop 65	IARC list 2B	
Cobalt sulfate heptahydrate		Prop 65			
Cobalt, ((2,2'-(1,2-Ethanediylbis (Nitrilomethylidyne)) Bis(6-Fluorophenolato))(2-)-N,N',O,O')-		EPA Haz list			
Cocaine		Prop 65			
Coconut oil diethanolamine condensate		IARC list Group 2B			
coconut oil diethanolamine condensate (cocamide diethanolamine)		Prop 65			
Codeine phosphate		Prop 65			
Coke Oven Emissions		KNOWN Carcinogens N	Prop 65	IARC list 1	
Colchicine		EPA Haz list	Prop 65		
Conjugated estrogens		Prop 65			
Copper cyanide		Acutely Toxic			
Coumaphos		EPA Haz list			
Coumatetralyl		EPA Haz list			
Creosotes		IARC list 2A	Prop 65		
Cresol, o-		EPA Haz list			
Crimidine		EPA Haz list			
Crotonaldehyde		EPA Haz list			
Crotonaldehyde, (E)-		EPA Haz list			
Cumene		IARC list Group 2B	Reasonably Anticipated NT	Prop 65	

Cumene Hydroperoxide		EPA Haz list		
Cupferron		Reasonably Anticipated	Prop 65	
Cyanazine		Prop 65		
Cyanides (soluble cyanide salts), not otherwise specified		Acutely Toxic		
Cyanogen		Acutely Toxic		
Cyanogen Bromide		EPA Haz list		
Cyanogen chloride		Acutely Toxic		
Cyanogen Iodide		EPA Haz list		
Cyanophos		EPA Haz list		
Cyanuric Fluoride		EPA Haz list		
Cycasin		IARC list 2B	Prop 65	
Cycloate		Prop 65		
Cycloheximide		Prop 65		
Cycloheximide		EPA Haz list		
Cyclohexylamine		EPA Haz list		
Cyclopenta[cd]pyrene		IARC list 2A	Prop 65	
Cyclophosphamide		IARC list 1	Prop 65	KNOWN Carcinogens NTP
Cyclosporin A		KNOWN Carcinogens NTP		
Cyclosporine		IARC list 1		
Cyhexatin		Prop 65		
Cytarabine		Prop 65		
Cytembena		Prop 65		
D&C Orange No. 17		Prop 65		
D&C Red No. 19		Prop 65		
D&C Red No. 8		Prop 65		
D&C Red No. 9		Prop 65		
Dacarbazine		Prop 65		
Dacarbazine		IARC list 2B	Prop 65	Reasonably Anticipated NTP
Daminozide		Prop 65		
Danazol		Prop 65		
Dantron (Chrysazin; 1,8-Dihydroxyanthraquinone)		IARC list 2B	Prop 65	Reasonably Anticipated NTP
Daunomycin		IARC list 2B	Prop 65	
Daunorubicin hydrochloride		Prop 65		
DDD (Dichlorodiphenyl-dichloroethane)		Prop 65		
DDE (Dichlorodiphenyl-dichloroethylene)		Prop 65		
DDT (4,4'-Dichlorodiphenyltrichloroethane)	50-29-3	IARC list 2A	Prop 65	
DDVP (Dichlorvos)		Prop 65		
Decaborane(14)		EPA Haz list		
Demeclocycline hydrochloride (internal use)		Prop 65		
Demeton		EPA Haz list		
Demeton-S-Methyl		EPA Haz list		
Des-ethyl atrazine (DEA)		Prop 65		
Des-isopropyl atrazine (DIA)		Prop 65		
di(2-Ethylhexyl) Phthalate		Reasonably Anticipated	Prop 65	
Di(2-ethylhexyl)phthalate		IARC list Group 2B		
Dialifor		EPA Haz list		
Diaminotoluene (mixed)		Prop 65		

Diazepam		Prop 65		
Diazoaminobenzene		Reasonably Anticipated	Prop 65	
Diazoxide		Prop 65		
Diazinon	333-41-5	IARC list 2A		
Dibenz[a,h]acridine (See Polycyclic Aromatic Hydrocarbons)		Reasonably Anticipated	IARC list 2B	Prop 65
Dibenz[a,c]anthracene		Prop 65		
Dibenz[a,h]anthracene		IARC list 2A	Prop 65	Reasonably Anticipated NTP
Dibenz[a,j]anthracene		Prop 65		
Dibenzanthracenes		Prop 65		
Dibenz[a,j]acridine		IARC list Group 2A		
Dibenz[a,j]acridine (See Polycyclic Aromatic Hydrocarbons)		Reasonably Anticipated	Prop 65	IARC list 2B
Dibenz[c,h]acridine		IARC list Group 2B		
Dibenzo[a,e]pyrene (See Polycyclic Aromatic Hydrocarbons)		Reasonably Anticipated	Prop 65	
Dibenzo[a,h]pyrene (See Polycyclic Aromatic Hydrocarbons)		Reasonably Anticipated	Prop 65	IARC list 2B
Dibenzo[a,i]pyrene (See Polycyclic Aromatic Hydrocarbons)		Reasonably Anticipated	Prop 65	IARC list 2B
Dibenzo[a,l]pyrene (See Polycyclic Aromatic Hydrocarbons)		Reasonably Anticipated	Prop 65	IARC list 2A
Diborane		EPA Haz list		
Dibromoacetic acid		Prop 65		
Dibromoacetic acid		IARC list Group 2B		
Dibromoacetonitrile		IARC list 2B	Prop 65	
Dibromoacetonitrile		IARC list Group 2B		
Dichloroacetic acid		IARC list 2B	Prop 65	
dichloroacetyl-1-oxa-4-azaspiro(4,5)-decane		Prop 65		
Dichlorodiphenyltrichloroethane (DDT)		IARC list 2A	Reasonably Anticipated NTP	
Dichloroethyl ether		EPA Haz list		
Dichloromethane (Methylene Chloride)	75-09-2	Reasonably Anticipated	Prop 65	IARC list 2A
Dichloromethyl ether		Acutely Toxic		
Dichloromethylphenylsilane		EPA Haz list		
Dichlorophene		Prop 65		
Dichlorophenylarsine		Acutely Toxic		
Dichlorphenamide		Prop 65		
Dichlorvos		IARC list 2B	EPA Haz list	
Diclofop-methyl		Prop 65		
Dicrotophos		EPA Haz list		
Dicumarol		Prop 65		
Dieldrin	60-57-1	IARC list 2A	Prop 65	Acutely Toxic
Diepoxybutane		Reasonably Anticipated	Prop 65	EPA Haz list
Diesel Exhaust Particulates		Reasonably Anticipated	Prop 65	IARC list 2B
diethanolamine		Prop 65		
Diethanolamine		IARC list Group 2B		
Diethyl Chlorophosphate		EPA Haz list		
Diethyl Sulfate		Reasonably Anticipated	Prop 65	IARC list 2A
Diethylarsine		Acutely Toxic		
Diethyl-p-nitrophenyl phosphate		Acutely Toxic		
Diethylstilbestrol		KNOWN Carcinogens N	Prop 65	IARC list 1
Diflunisal		Prop 65		
Digitoxin		EPA Haz list		

Diglycidyl ether		EPA Haz list			
Diglycidyl resorcinol ether		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Digoxin		IARC list 2B	EPA Haz list		
Dihydroergotamine mesylate		Prop 65			
Dihydrosafrole		IARC list 2B	Prop 65		
Di-isodecyl phthalate (DIDP)		Prop 65			
Diisononyl phthalate (DINP)		Prop 65	EPA Haz list		
Diisopropyl sulfate		IARC list 2B	Prop 65		
Diisopropylfluorophosphate (DFP)		Acutely Toxic			
Diltiazem hydrochloride		Prop 65			
Dimefox		EPA Haz list			
Dimethoate		EPA Haz list	Acutely Toxic		
Dimethyl Phosphorochloridothioate		EPA Haz list			
Dimethyl sulfate		IARC list 2A	Prop 65	Reasonably Antic	EPA Haz list
Dimethylarsenic acid		IARC list 2B			
Dimethylcarbamoyl chloride		IARC list 2A	Prop 65	Reasonably Anticipated NTP	
Dimethyldichlorosilane		EPA Haz list			
Dimethylhydrazine		EPA Haz list			
Dimethyl-p-Phenylenediamine		EPA Haz list			
Dimethylvinyl Chloride		Reasonably Anticipated	Prop 65		
Dimetilan		EPA Haz list	Acutely Toxic		
Di-*n*-butyl phthalate (DBP)		Prop 65			
Di-*n*-hexyl phthalate (DnHP)		Prop 65			
Dinitrocresol		EPA Haz list			
Dinitrotoluene (technical grade)		Prop 65			
Dinitrotoluene mixture, 2,4-/2,6-		Prop 65			
Dinocap		Prop 65			
Dinoseb		EPA Haz list	Prop 65	Acutely Toxic	
Dinoterb		EPA Haz list			
Di-*n*-propyl isocinchomeronate (MGK Repellent 326)		Prop 65			
Dioxathion		EPA Haz list			
Diphacinone		EPA Haz list			
Diphenylhydantoin (Phenytoin)		Prop 65			
Diphenylhydantoin (Phenytoin), sodium salt		Prop 65			
Diphosphoramide, Octamethyl-		EPA Haz list	Acutely Toxic		
Diphosphoric acid, tetraethyl ester		Acutely Toxic			
Direct Black 38 (technical grade)		Prop 65			
Direct Blue 6 (technical grade)		Prop 65			
Direct Brown 95 (technical grade)		Prop 65			
Disodium cyanodithioimidocarbonate		Prop 65			
Disperse Blue 1		Reasonably Anticipated	Prop 65	IARC list 2B	
Disulfoton		EPA Haz list	Acutely Toxic		
Dithiazanine Iodide		EPA Haz list			
Dithiobiuret		EPA Haz list	Acutely Toxic		
Diuron		Prop 65			
Doxorubicin hydrochloride (Adriamycin)		Prop 65			
Doxycycline (internal use)		Prop 65			

Doxycycline calcium (internal use)		Prop 65			
Doxycycline hyclate (internal use)		Prop 65			
Doxycycline monohydrate (internal use)		Prop 65			
Dyes Metabolized to 3,3´-Dimethoxybenzidine (See 3,3´-Dimethoxybenzidine and Dyes Metabolized to 3,3´-Dimethoxybenzidine)		Reasonably Anticipated NTP			
Dyes Metabolized to 3,3´-Dimethylbenzidine (See 3,3´-Dimethylbenzidine and Dyes Metabolized to 3,3´-Dimethylbenzidine)		Reasonably Anticipated NTP			
Dyes Metabolized to Benzidine (See Benzidine and Dyes Metabolized to Benzidine)		KNOWN Carcinogens NTP			
Emetine, Dihydrochloride		EPA Haz list			
Emissions from combustion of coal		Prop 65			
Emissions from high-temperature unrefined rapeseed oil		Prop 65			
Endosulfan		EPA Haz list	Acutely Toxic		
Endothall		Acutely Toxic			
Endothion		EPA Haz list			
Endrin		EPA Haz list	Prop 65	Acutely Toxic	
Engine exhaust, diesel		IARC list 2A			
Engine exhaust, gasoline		IARC list 2B			
Environmental tobacco smoke (ETS)		Prop 65			
Environmental Tobacco Smoke (See Tobacco Related Exposures)		KNOWN Carcinogens NTP			
Epichlorohydrin		IARC list 2A	Prop 65	Reasonably Antic	EPA Haz list
Epinephrine		Acutely Toxic			
EPN		EPA Haz list			
Epoxiconazole		Prop 65			
Epstein-Barr virus		IARC list 1	KNOWN Carcinogens NTP		
Ergocalciferol		EPA Haz list			
Ergotamine Tartrate		EPA Haz list	Prop 65		
Erionite		KNOWN Carcinogens N	Prop 65	IARC list 1	
Estradiol 17B		Prop 65			
Estragole		Prop 65			
Estrogen therapy, postmenopausal		IARC list 1			
Estrogen-progestogen menopausal therapy (combined)		IARC list 1	Prop 65		
Estrogen-progestogen oral contraceptives (combined)		IARC list 1			
Estrogens, Steroidal		KNOWN Carcinogens N	Prop 65		
Estrone		Prop 65			
Estropipate		Prop 65			
Ethanedinitrile		Acutely Toxic			
Ethanesulfonyl Chloride, 2-Chloro-		EPA Haz list			
Ethanimidothioc acid, 2-(dimethylamino)-N-[[(methylamino)carbonyl]oxy]-2-oxo-, methyl ester		Acutely Toxic			
Ethanimidothioic acid,N-[[(methylamino)carbonyl]oxy]-,methyl ester		Acutely Toxic			
Ethanol in alcoholic beverages		IARC list 1	Prop 65		
Ethanol, 1,2-Dichloro-, Acetate		EPA Haz list			
Ethinylestradiol		Prop 65			
Ethion		EPA Haz list			
Ethionamide		Prop 65			
Ethoprop		Prop 65			
Ethoprophos		EPA Haz list			
Ethyl acrylate		IARC list 2B	Prop 65		
Ethyl alcohol in alcoholic beverages		Prop 65			
Ethyl carbamate (Urethane)		IARC list 2A			

Ethyl cyanide		Acutely Toxic			
Ethyl dipropylthiocarbamate		Prop 65			
Ethyl Methanesulfonate		Reasonably Anticipated	Prop 65	IARC list 2B	
Ethyl-4,4'-dichlorobenzilate		Prop 65			
Ethylbenzene		IARC list 2B	Prop 65		
Ethylbis(2-Chloroethyl)Amine		EPA Haz list			
Ethylene dibromide		IARC list 2A	Prop 65		
Ethylene dichloride (1,2-Dichloroethane)		Prop 65			
Ethylene Fluorohydrin		EPA Haz list			
Ethylene glycol (ingested)		Prop 65			
Ethylene glycol monoethyl ether		Prop 65			
Ethylene glycol monoethyl ether acetate		Prop 65			
Ethylene Oxide		KNOWN Carcinogens N	IARC list 1	Prop 65	EPA Haz list
Ethylene Thiourea		Reasonably Anticipated	Prop 65		
Ethylenediamine		EPA Haz list			
Ethyleneimine		EPA Haz list	Prop 65	Acutely Toxic	
Ethylthiocyanate		EPA Haz list			
Etodolac		Prop 65			
Etoposide		IARC list 1	Prop 65		
Etoposide in combination with cisplatin and bleomycin		IARC list 1	Prop 65		
Etretinate		Prop 65			
Famphur		Acutely Toxic			
Fenamiphos		EPA Haz list			
Fenoxaprop ethyl		Prop 65			
Fenoxycarb		Prop 65			
Fensulfothion		EPA Haz list			
Filgrastim		Prop 65			
Fission products, including strontium-90		IARC list 1			
Fluazifop butyl		Prop 65			
Fluenetil		EPA Haz list			
Flunisolide		Prop 65			
Fluorine		EPA Haz list	Acutely Toxic		
Fluoroacetamide		EPA Haz list	Acutely Toxic		
Fluoroacetic Acid		EPA Haz list	Acutely Toxic		
Fluoroacetyl Chloride		EPA Haz list			
Fluoro-edenite fibrous amphibole		IARC list 1			
Fluorouracil		EPA Haz list	Prop 65		
Fluoxymesterone		Prop 65			
Flurazepam hydrochloride		Prop 65			
Flurbiprofen		Prop 65			
Flutamide		Prop 65			
Fluticasone propionate		Prop 65			
Fluvalinate		Prop 65			
Folpet		Prop 65			
Fonofos		EPA Haz list			
Formaldehyde		IARC list 1	EPA Haz list	KNOWN Carcinogens NTP	
Formaldehyde (Gas)		Reasonably Anticipated	Prop 65		

Formaldehyde Cyanohydrin		EPA Haz list			
Formetanate Hydrochloride		EPA Haz list	Acutely Toxic		
Formothion		EPA Haz list			
Formparanate		EPA Haz list	Acutely Toxic		
Fosthietan		EPA Haz list			
Frying, emissions from high-temperature		IARC list 2A			
Fuberidazole		EPA Haz list			
Fuel oils, residual (heavy)		IARC list 2B			
Fulminic acid, mercury(2+) salt		Acutely Toxic			
Fumonisin B1		IARC list 2B	Prop 65		
Furan		Reasonably Anticipated	Prop 65	IARC list 2B	EPA Haz list
Furazolidone		Prop 65			
Furfuryl alcohol	98-00-0	IARC list 2B	Prop 65		
furilazole		Prop 65			
Furmecyclox		Prop 65			
Fusarin C		Prop 65			
Fusarium moniliforme, toxins derived from (fumonisin B1, fumonisin B2, and fusarin C)		IARC list 2B			
Gallium arsenide		Prop 65			
Gallium Trichloride		EPA Haz list			
Ganciclovir		Prop 65			
Ganciclovir sodium		Prop 65			
Gasoline		IARC list 2B	Prop 65		
Gemfibrozil		Prop 65			
Gentian violet (Crystal violet)	548-62-9	Prop 65			
Ginkgo biloba extract		IARC list 2B			
Glass wool fibers (inhalable and biopersistent)		Reasonably Anticipated	Prop 65		
Glu-P-1 (2-Amino-6-methyldipyrido[1,2- a:3',2'-d]imidazole)		Prop 65			
Glu-P-1 (2-Amino-6-methyldipyrido[1,2-a:3',2'-d]imidazole)		IARC list 2B	Prop 65		
Glu-P-2 (2-Aminodipyrido[1,2-a:3',2'-d]imidazole)		IARC list 2B			
Glycidaldehyde		IARC list 2B	Prop 65		
Glycidol		Reasonably Anticipated	Prop 65	IARC list 2A	
Glycidyl methacrylate	106-91-2	IARC list 2A			
Glyphosate	1071-83-6	IARC list 2A			
Goldenseal root powder		IARC list 2B	Prop 65		
Goserelin acetate		Prop 65			
Griseofulvin		IARC list 2B	Prop 65		
Gyromitrin (Acetaldehyde methylformylhydrazone)		Prop 65			
Haematite mining (underground)		IARC list 1			
Halazepam		Prop 65			
Halobetasol propionate		Prop 65			
Haloperidol		Prop 65			
Halothane		Prop 65			
HC Blue 1		Prop 65			
HC Blue No.		IARC list 2B			
Helicobacter pylori (infection with)		IARC list 1			
Hepatitis B Virus		KNOWN Carcinogens N	IARC list 1		
Hepatitis C Virus		KNOWN Carcinogens N	IARC list 1		

Heptachlor		IARC list 2B	Prop 65	Acutely Toxic	
Heptachlor epoxide		Prop 65			
Herbal remedies containing plant species of the genus Aristolochia		Prop 65			
n-hexane	110-54-3	Prop 65			
Hexachlorobenzene		Prop 65			
Hexachlorobenzene		Reasonably Anticipated	Prop 65	IARC list 2B	
Hexachlorobutadiene		Prop 65			
Hexachlorocyclohexane (alpha isomer)		Prop 65			
Hexachlorocyclohexane (beta isomer)		Prop 65			
Hexachlorocyclohexane (gamma isomer)		Prop 65			
Hexachlorocyclohexane (technical grade)		Prop 65			
Hexachlorocyclohexane Isomers (See Lindane and Other Hexachlorocyclohexane Isomers)		Reasonably Anticipated	IARC list 2B		
Hexachlorocyclopentadiene		EPA Haz list			
Hexachlorodibenzodioxin		Prop 65			
Hexachloroethane		Reasonably Anticipated	Prop 65	IARC list 2B	
Hexaethyl tetraphosphate		Acutely Toxic			
Hexafluoroacetone		Prop 65			
Hexamethylenediamine, N,N'-Dibutyl-		EPA Haz list			
Hexamethylphosphoramide		Reasonably Anticipated	Prop 65	IARC list 2B	
Histrelin acetate		Prop 65			
Human immunodeficiency virus type 1 (infection with)		IARC list 1	KNOWN Carcinogens NTP		
Human immunodeficiency virus type 2 (infection with)		IARC list 2B			
Human Papillomas Viruses: Some Genital-Mucosal Types		KNOWN Carcinogens NTP			
Human papillomavirus type 68		IARC list 2A			
Human papillomavirus types 16, 18, 31, 33, 35, 39, 45, 51, 52, 56, 58, 59		IARC list 1			
Human T-cell lymphotropic virus type I		IARC list 1	KNOWN Carcinogens NTP		
Hydramethylnon		Prop 65			
Hydrazine and Hydrazine Sulfate	302-01-2	Reasonably Anticipated	Prop 65	IARC list 2A	EPA Haz list
Hydrazine sulfate		Prop 65			
Hydrazinecarbothioamide		Acutely Toxic			
Hydrazobenzene		Reasonably Anticipated	Prop 65		
Hydrochlorothiazide		IARC list 2B			
Hydrocyanic Acid		EPA Haz list	Acutely Toxic		
Hydrogen Chloride (gas only)		EPA Haz list			
Hydrogen cyanide		Acutely Toxic			
Hydrogen Fluoride		EPA Haz list			
Hydrogen Peroxide (Conc > 52%)		EPA Haz list			
Hydrogen phosphide		Acutely Toxic			
Hydrogen Selenide		EPA Haz list			
Hydrogen Sulfide		EPA Haz list			
Hydroquinone		EPA Haz list			
Hydroxyurea		Prop 65			
Idarubicin hydrochloride		Prop 65			
Ifosfamide		Prop 65			
Imazalil		Prop 65			
Indeno [1,2,3-cd]pyrene		Prop 65			
Indeno[1,2,3-cd]pyrene		IARC list 2B	Reasonably Anticipated NTP		

Indium phosphide		IARC list 2A	Prop 65		
Indium tin oxide	50926-11-9	IARC list 2B			
Iodine-131		Prop 65			
Ionizing radiation (all types)		IARC list 1			
Iprodione		Prop 65			
Iprovalicarb		Prop 65			
IQ (2-Amino-3-methylimidazo[4,5-f]quinoline)		IARC list 2A	Prop 65		
Iron and steel founding (occupational exposure during)		IARC list 1			
Iron Dextran Complex		Reasonably Anticipated	Prop 65		
Iron, Pentacarbonyl-		EPA Haz list			
Iron-dextran complex		IARC list 2B			
Isobenzan		EPA Haz list			
Isobutyl nitrite		Prop 65			
Isobutyronitrile		EPA Haz list			
Isocyanic Acid, 3,4-Dichlorophenyl Ester		EPA Haz list			
Isodrin		EPA Haz list	Acutely Toxic		
Isofluorphate		EPA Haz list			
Isolan		Acutely Toxic			
Isophorone Diisocyanate		EPA Haz list			
Isoprene		Reasonably Anticipated	Prop 65	IARC list 2B	
Isopropyl alcohol manufacture using strong acids		IARC list 1			
Isopropyl Chloroformate		EPA Haz list			
Isopropylmethyl-pyrazolyl Dimethylcarbamate		EPA Haz list			
Isopyrazam		Prop 65			
Isotretinoin		Prop 65			
Isoxaflutole		Prop 65			
JC polyomavirus (JCV)		IARC list Group 2B	KNOWN Carcinogens NTP		
Kaposi sarcoma herpesvirus		IARC list 1	KNOWN Carcinogens NTP		
Kava extract		IARC list 2B			
Kepone® (Chlordecone)		Reasonably Anticipated NTP			
Kresoxim-methyl		Prop 65			
Lactofen		Prop 65			
Lactonitrile		EPA Haz list			
Lasiocarpine		IARC list 2B	Prop 65		
Lead		IARC list 2B	Prop 65		
Lead acetate		Prop 65			
Lead and Lead Compounds		Reasonably Anticipated	Prop 65		
Lead compounds, inorganic		IARC list 2A			
Lead phosphate		Prop 65			
Lead subacetate		Prop 65			
Leather dust		IARC list 1	Prop 65		
Leptophos		EPA Haz list			
Leuprolide acetate		Prop 65			
Levodopa		Prop 65			
Levonorgestrel implants		Prop 65			
Lewisite		EPA Haz list			
Lindane and Other Hexachlorocyclohexane Isomers	58-89-9	IARC list 1	Reasonably Anticipated NT	Prop 65	EPA Haz list

Linuron		Prop 65		
Lithium carbonate		Prop 65		
Lithium citrate		Prop 65		
Lithium Hydride		EPA Haz list		
Lorazepam		Prop 65		
Lovastatin		Prop 65		
Lynestrenol		Prop 65		
Magenta		IARC list 2B		
Magenta production		IARC list 1		
Magnetic fields, extremely low-frequency		IARC list 2B		
Malaria (caused by infection with Plasmodium falciparum in holoendemic areas)		IARC list Group 2A		
Malathion	121-75-5	IARC list Group 2A	Prop 65	
Malonaldehyde, sodium salt		Prop 65		
Malononitrile		EPA Haz list		
Mancozeb		Prop 65		
Maneb		Prop 65		
Manganese dimethyldithiocarbamate.		Acutely Toxic		
Manganese, Tricarbonyl Methylcyclopentadienyl		EPA Haz list		
Manganese,bis(dimethylcarbamodithioato-S,S')-,		Acutely Toxic		
Marijuana smoke		Prop 65		
Mate, hot		IARC list 2A		
m-Cumenyl methylcarbamate.		Acutely Toxic		
m-Dinitrobenzene		Prop 65		
MeA-alpha-C (2-Amino-3-methyl-9H-pyrido[2,3-b]indole)		IARC list 2B	Prop 65	
Mebendazole		Prop 65		
Mechlorethamine		EPA Haz list		
Medroxyprogesterone acetate		IARC list 2B	Prop 65	
Megestrol acetate		Prop 65		
Melamine	108-78-1	IARC list 2B		
MeIQ (2-Amino-3,4-dimethylimidazo[4,5-f]quinoline)		IARC list 2B	Prop 65	
MeIQx (2-Amino-3,8-dimethylimidazo[4,5-f]quinoxaline)		IARC list 2B	Prop 65	
Melphalan		KNOWN Carcinogens N	Prop 65	IARC list 1
Menotropins		Prop 65		
Mepanipyrim		Prop 65		
Mephosfolan		EPA Haz list		
Meprobamate		Prop 65		
Mercaptopurine		Prop 65		
Mercuric Acetate		EPA Haz list		
Mercuric Chloride		EPA Haz list		
Mercuric Oxide		EPA Haz list		
Mercury and mercury compounds		Prop 65		
Mercury fulminate (R,T)		Acutely Toxic		
Mercury, (acetato-O)phenyl-		Acutely Toxic		
Merkel cell polyomavirus (MCV)		IARC list Group 2A	KNOWN Carcinogens NTP	
Merphalan		IARC list 2B	Prop 65	
Mestranol		Prop 65		
Metam potassium		Prop 65		

Methacrolein Diacetate		EPA Haz list			
Methacrylic Anhydride		EPA Haz list			
Methacrylonitrile		EPA Haz list			
Methacryloyl Chloride		EPA Haz list			
Methacryloyloxyethyl Isocyanate		EPA Haz list			
Methacycline hydrochloride		Prop 65			
Metham sodium		Prop 65			
Methamidophos		EPA Haz list			
Methanamine, N-methyl-N-nitroso-		Acutely Toxic			
Methane, isocyanato-		Acutely Toxic			
Methane, oxybis[chloro-		Acutely Toxic			
Methane, tetranitro- (R)		Acutely Toxic			
Methanesulfonyl Fluoride		EPA Haz list			
Methanethiol, trichloro-		Acutely Toxic			
Methanimidamide, N,N-dimethyl-N'-[3-[[(methylamino)-carbonyl]oxy]phenyl]-, monohydrochloride		Acutely Toxic			
Methanol		Prop 65			
Methazole		Prop 65			
Methidathion		EPA Haz list			
Methimazole		Prop 65			
Methiocarb		EPA Haz list	Acutely Toxic		
Methomyl		EPA Haz list	Acutely Toxic		
Methotrexate		Prop 65			
Methotrexate sodium		Prop 65			
Methoxsalen with Ultraviolet A Therapy (PUVA)		KNOWN Carcinogens N	IARC list 1		
Methoxyethylmercuric Acetate		EPA Haz list			
Methyl 2-Chloroacrylate		EPA Haz list			
Methyl Bromide		EPA Haz list	Prop 65		
Methyl carbamate		Prop 65			
Methyl chloride		Prop 65			
Methyl Chloroformate		EPA Haz list			
Methyl Hydrazine		EPA Haz list	Acutely Toxic		
Methyl iodide		Prop 65			
Methyl isobutyl ketone		Prop 65			
Methyl isobutyl ketone		IARC list Group 2B	Prop 65		
Methyl Isocyanate		EPA Haz list	Prop 65	Acutely Toxic	
Methyl Isothiocyanate		EPA Haz list			
Methyl Mercaptan		EPA Haz list			
Methyl mercury		Prop 65			
Methyl Methanesulfonate		Reasonably Anticipated	Prop 65	IARC list 2A	
Methyl n-butyl ketone		Prop 65			
Methyl parathion		Acutely Toxic			
Methyl Phenkapton		EPA Haz list			
Methyl Phosphonic Dichloride		EPA Haz list			
Methyl Thiocyanate		EPA Haz list			
Methyl Vinyl Ketone		EPA Haz list			
Methylarsonic acid		IARC list 2B			
Methylazoxymethanol		Prop 65			

Methylazoxymethanol acetate		IARC list 2B	Prop 65	
Methyleugenol		IARC list Group 2B	Reasonably Anticipated NT	Prop 65
Methylhydrazine and its salts		Prop 65		
Methylhydrazine sulfate		Prop 65		
Methylmercuric Dicyanamide		EPA Haz list		
Methylmercury compounds		IARC list 2B	Prop 65	
Methyltestosterone		Prop 65		
Methylthiouracil		IARC list 2B	Prop 65	
Methyltrichlorosilane		EPA Haz list		
Metiram		Prop 65		
Metolcarb		EPA Haz list	Acutely Toxic	
Metronidazole		Reasonably Anticipated	Prop 65	IARC list 2B
Mevinphos		EPA Haz list		
Mexacarbate		EPA Haz list	Acutely Toxic	
Michler´s Ketone [4,4´-(Dimethylamino)benzophenone]		Reasonably Anticipated NTP		
Michler's base [4,4¢-methylenebis(N,N-dimethyl)-benzenamine]		IARC list 2B		
Michler's ketone [4,4¢-Bis(dimethylamino)benzophenone]		IARC list 2B	Prop 65	
Microcystin-LR		IARC list 2B		
Midazolam hydrochloride		Prop 65		
Mineral oils, untreated or mildly treated		IARC list 1	KNOWN Carcinogens NTP	
Minocycline hydrochloride (internal use)		Prop 65		
Mirex		Reasonably Anticipated	Prop 65	IARC list 2B
Misoprostol		Prop 65		
Mitomycin C		IARC list 2B	Prop 65	EPA Haz list
Mitoxantrone		IARC list 2B	Prop 65	
Molinate		Prop 65		
Molybdenum trioxide	1313-27-5	IARC list 2B		
Monocrotaline		IARC list 2B	Prop 65	
Monocrotophos		EPA Haz list		
MOPP (vincristine-prednisone-nitrogen mustard-procarbazine mixture)		Prop 65		
MOPP and other combined chemotherapy including alkylating agents		IARC list 1		
Muscimol		EPA Haz list		
Mustard Gas		KNOWN Carcinogens N	Prop 65	EPA Haz list
MX (3-chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone)		Prop 65		
Myclobutanil		Prop 65		
N,N-Bis(2-chloroethyl)-2-naphthylamine (Chlornapazine)		Prop 65		
N,N'-Diacetylbenzidine		IARC list 2B	Prop 65	
N,N-Dimethylacetamide	127-19-5	Prop 65	IARC list 2B	
N,N-Dimethylformamide	68-12-2	IARC list 2A		
N,N-Dimethylacetamide	127-19-5	Prop 65		
N ,*N* -Dimethyl-*p* -toluidine	99-97-8	IARC list 2B	IARC list 2B	
N-[4-(5-Nitro-2-furyl)-2-thiazolyl]acetamide		IARC list 2B	Prop 65	
Nabam		Prop 65		
Nafarelin acetate		Prop 65		
Nafenopin		IARC list 2B	Prop 65	
Nalidixic acid		Prop 65		
Naphthalene		Reasonably Anticipated	Prop 65	IARC list 2B

N-Carboxymethyl-N-nitrosourea		Prop 65			
Neomycin sulfate (internal use)		Prop 65			
N-Ethyl-N-nitrosourea		IARC list 2A			
Netilmicin sulfate		Prop 65			
Neutrons (See Ionizing Radiation)		KNOWN Carcinogens N	IARC list 1		
Nickel (Metallic) (See Nickel Compounds and Metallic Nickel)	varies	Reasonably Anticipated	Prop 65		
Nickel acetate		Prop 65			
Nickel carbonate		Prop 65			
Nickel Carbonyl		EPA Haz list	Prop 65	Acutely Toxic	
Nickel Compounds (See Nickel Compounds and Metallic Nickel)		KNOWN Carcinogens N	Prop 65	IARC list 1	
Nickel cyanide		Acutely Toxic			
Nickel hydroxide		Prop 65			
Nickel oxide		Prop 65			
Nickel refinery dust from the pyrometallurgical process		Prop 65			
Nickel subsulfide		Prop 65			
Nickel, metallic and alloys		IARC list 2B			
Nickelocene		Prop 65			
Nicotine		EPA Haz list	Prop 65	Acutely Toxic	
Nicotine Sulfate		EPA Haz list			
Nifedipine		Prop 65			
Nimodipine		Prop 65			
Niridazole		IARC list 2B	Prop 65		
Nitrapyrin		Prop 65			
Nitrate or nitrite (ingested) under conditions that result in endogenous nitrosation		IARC list 2A			
Nitric Acid		EPA Haz list			
Nitric Oxide		EPA Haz list	Acutely Toxic		
Nitrilotriacetic acid and its salts		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Nitrilotriacetic acid, trisodium salt monohydrate		Prop 65			
Nitrobenzene		Reasonably Anticipated	Prop 65	IARC list 2B	EPA Haz list
Nitrocyclohexane		EPA Haz list			
Nitrofen (technical-grade)		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Nitrofurantoin		Prop 65			
Nitrofurazone		Prop 65			
Nitrogen Dioxide		EPA Haz list	Acutely Toxic		
Nitrogen mustard		IARC list 2A	Prop 65		
Nitrogen Mustard Hydrochloride		Reasonably Anticipated	Prop 65		
Nitrogen mustard N-oxide		IARC list 2B	Prop 65		
Nitrogen mustard N-oxide hydrochloride		Prop 65			
Nitrogen oxide NO		Acutely Toxic			
Nitroglycerine		Acutely Toxic			
Nitromethane		Reasonably Anticipated	Prop 65	IARC list 2B	
Nitrosodimethylamine		EPA Haz list			
N-Nitrosohexamethyleneimine	932-83-2	Prop 65			
Nitrous oxide		Prop 65			
N-Methyl-N´-nitro-N-nitrosoguanidine (MNNG)		IARC list 2A	Prop 65	Reasonably Anticipated NTP	
N-Methyl-N-nitrosourea		IARC list 2A			
N-Methyl-N-nitrosourethane		IARC list 2B			

N-Methylolacrylamide		Prop 65			
N-Methylpyrrolidone		Prop 65			
N-Nitrosodiethanolamine		Reasonably Anticipated	Prop 65	IARC list 2B	
N-Nitrosodiethylamine		IARC list 2A	Prop 65	Reasonably Anticipated NTP	
N-Nitrosodimethylamine		Reasonably Anticipated	Prop 65	IARC list 2A	Acutely Toxic
N-Nitrosodi-n-butylamine		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
N-Nitrosodi-n-propylamine		Reasonably Anticipated	Prop 65	IARC list 2B	
N-Nitrosodiphenylamine		Prop 65			
N-Nitrosomethyl-n-butylamine		Prop 65			
N-Nitrosomethyl-n-decylamine		Prop 65			
N-Nitrosomethyl-n-dodecylamine		Prop 65			
N-Nitrosomethyl-n-heptylamine		Prop 65			
N-Nitrosomethyl-n-hexylamine		Prop 65			
N-Nitrosomethyl-n-nonylamine		Prop 65			
N-Nitrosomethyl-n-octylamine		Prop 65			
N-Nitrosomethyl-n-pentylamine		Prop 65			
N-Nitrosomethyl-n-propylamine		Prop 65			
N-Nitrosomethyl-n-tetradecylamine		Prop 65			
N-Nitrosomethyl-n-undecylamine		Prop 65			
N-Nitrosomethylethylamine		IARC list 2B	Prop 65		
N-Nitrosomethylvinylamine		Reasonably Anticipated	Prop 65	IARC list 2B	Acutely Toxic
N-Nitrosomorpholine		Reasonably Anticipated	Prop 65	IARC list 2B	
N-Nitroso-N-ethylurea		Reasonably Anticipated	Prop 65		
N-Nitroso-N-methylurea		Reasonably Anticipated	Prop 65		
N-Nitroso-N-methylurethane		Prop 65			
N-Nitrosonornicotine		Reasonably Anticipated	Prop 65		
N'-Nitrosonornicotine (NNN) and 4-(NNitrosomethylamino)-1-(3-pyridyl)-1-butanone (NNK)		IARC list 1			
N-Nitrosopiperidine		Reasonably Anticipated	Prop 65	IARC list 2B	
N-Nitrosopyrrolidine		Reasonably Anticipated	Prop 65	IARC list 2B	
N-Nitrososarcosine		Reasonably Anticipated	Prop 65	IARC list 2B	
Norbormide		EPA Haz list			
Norethisterone		Reasonably Anticipated	Prop 65		
Norethisterone (Norethindrone) /Ethinyl estradiol		Prop 65			
Norethisterone (Norethindrone) /Mestranol		Prop 65			
Norethisterone acetate (Norethindrone acetate)		Prop 65			
Norethynodrel		Prop 65			
Norgestrel		Prop 65			
O,O-Diethyl O-pyrazinyl phosphorothioate		Acutely Toxic			
o,p'-DDT		Prop 65			
o-Aminoazotoluene		Reasonably Anticipated	Prop 65		
o -Anisidine		Prop 65	EPA Haz list		
o-Anisidine Hydrochloride		Reasonably Anticipated	Prop 65		
Ochratoxin A		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Octamethylpyrophosphoramide		Acutely Toxic			
o -Dinitrobenzene		Prop 65			
Oil Orange SS		IARC list 2B	Prop 65		
o-Nitroanisole		Reasonably Anticipated	Prop 65		

o-Nitrotoluene		Prop 65	Reasonably Anticipated NTP		
o-Phenylenediamine	95-54-5	Prop 65	IARC list 2B		
o-Phenylenediamine and its salts		Prop 65			
o-Phenylenediamine dihydochloride	615-28-1	Prop 65	IARC list 2B		
o-Phenylphenate, sodium		Prop 65			
o-Phenylphenol		Prop 65			
o-Aminoazotoluene		IARC list 2B			
o-Anisidine 2B 73 1999		IARC list 2B			
o-Toluidine		IARC list 1	KNOWN Carcinogens NTP	Prop 65	
o-Toluidine hydrochloride		Prop 65			
Opisthorchis viverrini (infection with)		IARC list 1			
Oral contraceptives, combined		Prop 65			
Oral contraceptives, sequential		Prop 65			
Organorhodium Complex (PMN–82–147)		EPA Haz list			
Oryzalin		Prop 65			
Osmium tetroxide		Acutely Toxic			
Ouabain		EPA Haz list			
Oxadiazon		Prop 65			
Oxamyl		EPA Haz list	Acutely Toxic		
Oxazepam		IARC list 2B	Prop 65		
Oxetane, 3,3-Bis(Chloromethyl)-		EPA Haz list			
Oxydemeton methyl		Prop 65			
Oxydisulfoton		EPA Haz list			
Oxymetholone		Reasonably Anticipated	Prop 65		
Oxytetracycline (internal use)		Prop 65			
Oxytetracycline hydrochloride (internal use)		Prop 65			
Oxythioquinox (Chinomethionat)		Prop 65			
Ozone		EPA Haz list			
p,p'-DDT		Prop 65			
p-a,a,a- Tetrachlorotoluene		Prop 65			
Paclitaxel		Prop 65			
Palygorskite (Attapulgite) (long fibres, > 5 micrometres)		IARC list 2B	Prop 65		
p-Aminoazobenzene		Prop 65			
p-chloro-α,α,α-trifluorotoluene (para-Chlorobenzotrifluoride, PCBTF)		Prop 65			
Panfuran S (containing dihydroxymethylfuratrizine)		IARC list 2B	Prop 65		
para-Aminoazobenzene		IARC list 2B			
para-Chloroaniline		IARC list 2B			
para-Cresidine		IARC list 2B	EPA Haz list		
para-Dichlorobenzene		IARC list 2B			
para-Dimethylaminoazobenzene		IARC list 2B			
para-Nitroanisole	100-17-4	Prop 65	IARC list 2B		
Paramethadione		Prop 65			
Paraquat Dichloride		EPA Haz list			
Paraquat Methosulfate		EPA Haz list			
Parathion	56-38-2	IARC list 2B	EPA Haz list	Acutely Toxic	Prop 65
Parathion-Methyl		EPA Haz list			
Paris Green		EPA Haz list			

p-Chloroaniline		Prop 65	Acutely Toxic	
p-Chloroaniline hydrochloride		Prop 65		
p-Chloro-o-toluidine and p-Chloro-o-toluidine Hydrochloride		Reasonably Anticipated	Prop 65	
p- Chloro-*o*-toluidine, hydrochloride		Prop 65		
p- Chloro-*o*-toluidine, strong acid salts of		Prop 65		
p-Cresidine		Reasonably Anticipated	Prop 65	
p-Dichlorobenzene		Prop 65		
p-Dinitrobenzene		Prop 65		
Penicillamine		Prop 65		
Pentaborane		EPA Haz list		
pentabromodiphenyl ether mixture [DE-71 (technical grade)]		Prop 65		
Pentachlorophenol and by-products of its synthesis	87-86-5	IARC list 1	Prop 65	Reasonably Anticipated NTP
Pentadecylamine		EPA Haz list		
Pentobarbital sodium		Prop 65		
Pentosan polysulfate sodium		IARC list 2B		
Pentostatin		Prop 65		
Peracetic Acid		EPA Haz list		
Perchloromethylmercaptan		EPA Haz list		
Perfluorooctane sulfonate (PFOS)	1763-23-1	Prop 65		
Perfluorooctanoic acid (PFOA)	335-67-1	IARC list 2B	Prop 65	
Pertuzumab		Prop 65		
Petroleum refining (occupational exposures in)		IARC list 2A		
Phenacemide		Prop 65		
Phenacetin (See Phenacetin and Analgesic Mixtures Containing Phenacetin)		Reasonably Anticipated	Prop 65	IARC list 1
Phenacetin, analgesic mixtures containing		IARC list 1		
Phenazopyridine		Prop 65		
Phenazopyridine Hydrochloride		Reasonably Anticipated	Prop 65	IARC list 2B
Phenesterin		Prop 65		
Phenobarbital		IARC list 2B	Prop 65	
Phenol		EPA Haz list		
Phenol, (3,5-dimethyl-4-(methylthio)-,methylcarbamate		Acutely Toxic		
Phenol, 2-(1-methylpropyl)-4,6-dinitro-		Acutely Toxic		
Phenol, 2,2'-Thiobis(4-Chloro-6-Methyl)-		EPA Haz list		
Phenol, 2,4,6-trinitro-, ammonium salt ®		Acutely Toxic		
Phenol, 2,4-dinitro-		Acutely Toxic		
Phenol, 2-cyclohexyl-4,6-dinitro-		Acutely Toxic		
Phenol, 2-methyl-4,6-dinitro-, & salts		Acutely Toxic		
Phenol, 3-(1-Methylethyl)-, Methylcarbamate		EPA Haz list	Acutely Toxic	
Phenol, 3-methyl-5-(1-methylethyl)-,methyl carbamate.		Acutely Toxic		
Phenol, 4-(dimethylamino)-3,5-dimethyl-, methylcarbamate (ester).		Acutely Toxic		
Phenolphthalein		Reasonably Anticipated	Prop 65	IARC list 2B
Pentosan polysulfate sodium		Prop 65	IARC list 2B	
Phenoxarsine, 10,10'-Oxydi-		EPA Haz list		
Phenoxybenzamine		Prop 65		
Phenoxybenzamine Hydrochloride		Reasonably Anticipated	Prop 65	IARC list 2B
Phenprocoumon		Prop 65		
Phenyl Dichloroarsine		EPA Haz list		

Phenyl glycidyl ether		IARC list 2B	
Phenylhydrazine		Prop 65	
Phenylhydrazine and its salts		Prop 65	
Phenylhydrazine Hydrochloride		EPA Haz list	Prop 65
Phenylmercury Acetate		EPA Haz list	Acutely Toxic
Phenylphosphine		Prop 65	
Phenylsilatrane		EPA Haz list	
Phenylthiourea		EPA Haz list	Acutely Toxic
Phenytoin		Reasonably Anticipated	IARC list 2B
PhIP (2-Amino-1-methyl-6-phenylimidazo[4,5-b]pyridine)		IARC list 2B	Prop 65
Phorate		EPA Haz list	Acutely Toxic
Phosacetim		EPA Haz list	
Phosfolan		EPA Haz list	
Phosgene		EPA Haz list	Acutely Toxic
Phosphamidon		EPA Haz list	
Phosphine		EPA Haz list	Acutely Toxic
Phosphonothioic Acid, Methyl-, O-(4-Nitrophenyl) O-Phenyl Ester		EPA Haz list	
Phosphonothioic Acid, Methyl-, O-Ethyl O-(4-(Methylthio) Phenyl) Ester		EPA Haz list	
Phosphonothioic Acid, Methyl-, S-(2-(Bis(1Methylethyl)Amino)Ethyl) O-Ethyl Ester		EPA Haz list	
Phosphoric acid, diethyl 4-nitrophenylester		Acutely Toxic	
Phosphoric Acid, Dimethyl 4-(Methylthio)Phenyl Ester		EPA Haz list	
Phosphorodithioic acid, O,O-diethyl S-[2-(ethylthio)ethyl] ester		Acutely Toxic	
Phosphorodithioic acid, O,O-diethyl S-[2-(ethylthio)methyl] ester		Acutely Toxic	
Phosphorodithioic acid, O,O-dimethyl S-[2-(methylamino)-2-oxoethyl] ester		Acutely Toxic	
Phosphorofluoridic acid, bis(1-methylethyl) ester		Acutely Toxic	
Phosphorothioic acid, O,O,-dimethyl O(4-nitrophenyl) ester		Acutely Toxic	
Phosphorothioic acid, O,O-diethyl O-(4-nitrophenyl) ester		Acutely Toxic	
Phosphorothioic acid, O,O-diethyl O-pyrazinyl ester		Acutely Toxic	
Phosphorothioic Acid, O,O-Dimethyl-S-(2-Methylthio) Ethyl Ester		EPA Haz list	
Phosphorothioic acid,O-[4-[(dimethylamino)sulfonyl]phenyl] O,O-dimethyl ester		Acutely Toxic	
Phosphorus		EPA Haz list	
Phosphorus Oxychloride		EPA Haz list	
Phosphorus Pentachloride		EPA Haz list	
Phosphorus Trichloride		EPA Haz list	
Phosphorus-32, as phosphate		IARC list 1	
Physostigmine		EPA Haz list	Acutely Toxic
Physostigmine, Salicylate (1:1)		EPA Haz list	Acutely Toxic
Picrotoxin		EPA Haz list	
Pimozide		Prop 65	
Pioglitazone		IARC list 2B	Prop 65
Piperidine		EPA Haz list	
Pipobroman		Prop 65	
Pirimicarb		Prop 65	
Pirimifos-Ethyl		EPA Haz list	
Plicamycin		Prop 65	
Plumbane, tetraethyl-		Acutely Toxic	
Plutonium		IARC list 1	

p-Nitroaniline		Acutely Toxic			
p-Nitrosodiphenylamine		Prop 65			
Polybrominated Biphenyls (PBBs)		Reasonably Anticipated	Prop 65	IARC list 2A	
Polychlorinated Biphenyls (PCBs)		Reasonably Anticipated	Prop 65	IARC list 1	
Polychlorinated dibenzofurans		Prop 65			
Polychlorinated dibenzo-*p*-dioxins		Prop 65			
Polychlorophenols and their sodium salts		IARC list 2B			
Polycyclic Aromatic Hydrocarbons (PAHs)		Reasonably Anticipated NTP			
Polygeenan		Prop 65			
Ponceau 3R		IARC list 2B			
Ponceau MX		Prop 65			
Ponceau MX		IARC list 2B			
Potassium Arsenite		EPA Haz list			
Potassium bromate		IARC list 2B	Prop 65		
Potassium Cyanide		EPA Haz list	Acutely Toxic		
Potassium dimethyldithiocarbamate		Prop 65			
Potassium Silver Cyanide		EPA Haz list	Acutely Toxic		
Pravastatin sodium		Prop 65			
Prednisolone sodium phosphate		Prop 65			
Primidone		IARC list 2B	Prop 65		
Procarbazine		Prop 65			
Procarbazine Hydrochloride		Reasonably Anticipated	Prop 65	IARC list 2A	
Procymidone		Prop 65			
Progesterone		Reasonably Anticipated	Prop 65		
Progestins		IARC list 2B			
Progestogen-only contraceptives		IARC list 2B			
Promecarb		EPA Haz list	Acutely Toxic		
Pronamide		Prop 65			
Propachlor		Prop 65			
Propanal, 2-methyl-2-(methyl-sulfonyl)-, O-[(methylamino)carbonyl] oxime.		Acutely Toxic			
Propanal, 2-methyl-2-(methylthio)-,O-[(methylamino)carbonyl]oxime		Acutely Toxic			
Propanenitrile		Acutely Toxic			
Propanenitrile, 2-hydroxy-2-methyl-		Acutely Toxic			
Propanenitrile, 3-chloro-		Acutely Toxic			
Propargite		Prop 65			
Propargyl alcohol		Acutely Toxic			
Propargyl Bromide (3-Bromopropyne)		EPA Haz list			
Propazine		Prop 65			
Propiolactone, Beta-		EPA Haz list			
Propionitrile		EPA Haz list			
Propionitrile, 3-Chloro-		EPA Haz list			
Propiophenone, 4-Amino-		EPA Haz list			
Propoxur		Prop 65			
Propyl Chloroformate		EPA Haz list			
Propylene glycol mono-*t*-butyl ether		Prop 65			
Propylene Oxide		Reasonably Anticipated	Prop 65	IARC list 2B	EPA Haz list
Propyleneimine		EPA Haz list			

Propylthiouracil		Reasonably Anticipated	Prop 65	IARC list 2B	
Prothoate		EPA Haz list			
Pulegone		IARC list Group 2B	Prop 65		
pymetrozine		Prop 65			
Pyrene		EPA Haz list			
Pyridine	110-86-1	IARC list Group 2B	Prop 65		
Pyridine, 2-Methyl-5-Vinyl-		EPA Haz list			
Pyridine, 3-(1-methyl-2-pyrrolidinyl)-, (S)-, & salts		Acutely Toxic			
Pyridine, 4-Amino-		EPA Haz list			
Pyridine, 4-Nitro-,l-Oxide		EPA Haz list			
Pyrimethamine		Prop 65			
Pyriminil		EPA Haz list			
Pyrrolo[2,3-b]indol-5-ol,1,2,3,3a,8,8a-hexahydro-1,3a,8- trimethyl-, methylcarbamate (ester), (3aS-cis)-.		Acutely Toxic			
Quazepam		Prop 65			
Quinoline and its strong acid salts	91-22-5	IARC list Group 2B	Prop 65		
Quizalofop-ethyl		Prop 65			
Radiofrequency electromagnetic fields (Includes radiofrequency electromagnetic fields from wireless phones)		IARC list Group 2B			
Radioiodines, including iodine-131		IARC list Group 1			
Radionuclides		IARC list Group 1	Prop 65		
Radon (See Ionizing Radiation)		KNOWN Carcinogens NTP			
Reserpine		Reasonably Anticipated	Prop 65		
Residual (heavy) fuel oils		Prop 65			
Resmethrin		Prop 65			
Ribavirin		Prop 65			
Riddelliine		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Rifampin		Prop 65			
S,S,S-Tributyl phosphorotrithioate		Prop 65			
Safrole		Reasonably Anticipated	Prop 65	IARC list 2B	
Salcomine		EPA Haz list			
Salted fish, Chinese-style		Prop 65			
Sarin		EPA Haz list			
Schistosoma haematobium (infection with)		IARC list Group 1			
Schistosoma japonicum (infection with)		IARC list 2B			
Secobarbital sodium		Prop 65			
Sedaxane		Prop 65			
Selenious Acid		EPA Haz list			
Selenious acid, dithallium(1+) salt		Acutely Toxic			
Selenium Oxychloride		EPA Haz list			
Selenium Sulfide		Reasonably Anticipated	Prop 65		
Selenourea		Acutely Toxic			
Semicarbazide Hydrochloride		EPA Haz list			
Semustine [1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea, Methyl-CCNU]		IARC list Group 1			
Sermorelin acetate		Prop 65			
Shale oils		IARC list Group 1	Prop 65		
Silane, (4-Aminobutyl)Diethoxymethyl-		EPA Haz list			
Silica dust, crystalline, in the form of quartz or cristobalite		IARC list Group 1			
Silica, Crystalline (Respirable Size)		KNOWN Carcinogens N	Prop 65		

Silicon carbide, fibrous	308076-74-6	IARC list 2B			
Silicon carbide whiskers	409-21-2	IARC list 2A			
Silver cyanide		Acutely Toxic			
Simazine		Prop 65			
Sedaxane		Prop 65			
Smokeless Tobacco (See Tobacco Related Exposures)		KNOWN Carcinogens NTP			
Sodium Arsenate		EPA Haz list			
Sodium Arsenite		EPA Haz list			
Sodium Azide ($Na(N_3)$)		EPA Haz list	Acutely Toxic		
Sodium Cacodylate		EPA Haz list			
Sodium Cyanide (Na(CN))		EPA Haz list	Acutely Toxic		
Sodium dimethyldithiocarbamate		Prop 65			
Sodium Fluoroacetate		EPA Haz list	Prop 65		
Sodium ortho-phenylphenate		IARC list 2B			
Sodium Selenate		EPA Haz list			
Sodium Selenite		EPA Haz list			
Sodium Tellurite		EPA Haz list			
Solar Radiation (See Ultraviolet Radiation Related Exposures)		KNOWN Carcinogens N	IARC list Group 1		
Soots		KNOWN Carcinogens N	Prop 65		
Spirodiclofen		Prop 65			
Spironolactone		Prop 65			
Stannane, Acetoxytriphenyl-		EPA Haz list			
Stanozolol		Prop 65			
Sterigmatocystin		IARC list 2B	Prop 65		
Streptomycin sulfate		Prop 65			
Streptozotocin		Reasonably Anticipated	Prop 65	IARC list 2B	
Strong Inorganic Acid Mists Containing Sulfuric Acid		KNOWN Carcinogens N	Prop 65		
Strychnidin-10-one, & salts		Acutely Toxic			
Strychnidin-10-one, 2,3-dimethoxy-		Acutely Toxic			
Strychnine		EPA Haz list			
Strychnine Sulfate		EPA Haz list	Acutely Toxic		
Styrene		IARC list 2B	Reasonably Anticipated NT	Prop 65	Prop 65
Styrene oxide		Prop 65			
Styrene-7,8-oxide	96-09-3	Reasonably Anticipated	IARC list 2A		
Sulfallate		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Sulfasalazine (salicylazosulfapyridine)		IARC list 2B	Prop 65		
Sulfotep		EPA Haz list			
Sulfoxide, 3-Chloropropyl Octyl		EPA Haz list			
Sulfur Dioxide		EPA Haz list	Prop 65		
Sulfur mustard		IARC list Group 1			
Sulfur Tetrafluoride		EPA Haz list			
Sulfur Trioxide		EPA Haz list			
Sulfuric Acid		EPA Haz list	KNOWN Carcinogens NTP		
Sulfuric acid, dithallium(1+) salt		Acutely Toxic			
Sulindac		Prop 65			
Sunlamps or Sunbeds, Exposure to (See Ultraviolet Radiation Related Exposures)		KNOWN Carcinogens NTP			
Tabun		EPA Haz list			

Talc containing asbestiform fibers		Prop 65			
Tamoxifen		IARC list Group 1	Prop 65	KNOWN Carcinogens NTP	
Tamoxifen citrate		Prop 65			
Tellurium Hexafluoride		EPA Haz list			
Temazepam		Prop 65			
Teniposide		IARC list 2A	Prop 65		
TEPP		EPA Haz list			
Terbacil		Prop 65			
Terbufos		EPA Haz list			
Teriparatide		Prop 65			
Terrazole		Prop 65			
Testosterone and its esters		Prop 65			
Testosterone cypionate		Prop 65			
Testosterone enanthate		Prop 65			
Tetrabromobisphenol A	79-94-7	IARC list 2A			
Tetrachloroethylene (Perchloroethylene)		IARC list 2A	Prop 65	Reasonably Anticipated NTP	
Tetrachlorvinphos	22248-79-9	IARC list 2B	Prop 65		
Tetracycline (internal use)		Prop 65			
Tetracycline hydrochloride (internal use)		Prop 65			
Tetracyclines (internal use)		Prop 65			
Tetraethyl lead		EPA Haz list	Acutely Toxic		
Tetraethyl pyrophosphate		Acutely Toxic			
Tetraethyldithiopyrophosphate		Acutely Toxic			
Tetraethyltin		EPA Haz list			
Tetrafluoroethylene	116-14-3	Reasonably Anticipated	Prop 65	IARC list 2A	
Δ9-Tetrahydrocannabinol (Δ9-THC)	5957-75-5	Prop 65			
Tetrahydrofuran	109-99-9	IARC list 2B			
Tetramethyllead		EPA Haz list			
Tetranitromethane		Reasonably Anticipated	Prop 65	IARC list 2B	EPA Haz list
Tetraphosphoric acid, hexaethyl ester		Acutely Toxic			
Thalidomide		Prop 65			
Thallic oxide		Acutely Toxic			
Thallium Sulfate		EPA Haz list	Acutely Toxic		
Thallium(I) selenite		Acutely Toxic			
Thallous Carbonate		EPA Haz list			
Thallous Chloride		EPA Haz list			
Thallous Malonate		EPA Haz list			
Thallous Sulfate		EPA Haz list			
Thioacetamide		Reasonably Anticipated	Prop 65	IARC list 2B	
Thiocarbazide		EPA Haz list			
Thiodicarb		Prop 65			
Thiodiphosphoric acid, tetraethylester		Acutely Toxic			
Thiofanox		EPA Haz list	Acutely Toxic		
Thioguanine		Prop 65			
Thioimidodicarbonic diamide		Acutely Toxic			
Thionazin		EPA Haz list			
Thiophanate methyl		Prop 65			

Thiophenol		EPA Haz list	Acutely Toxic		
Thiosemicarbazide		EPA Haz list	Acutely Toxic		
Thiotepa		KNOWN Carcinogens N	IARC list Group 1		
Thiouracil		IARC list 2B	Prop 65		
Thiourea		Reasonably Anticipated	Prop 65		
Thiourea, (2-Chlorophenyl)-		EPA Haz list	Acutely Toxic		
Thiourea, (2-Methylphenyl)-		EPA Haz list			
Thiourea, 1-naphthalenyl-		Acutely Toxic			
Thiourea, phenyl-		Acutely Toxic			
Thorium Dioxide (See Ionizing Radiation)		KNOWN Carcinogens N	Prop 65		
Thorium-232 and its decay products		IARC list Group 1			
Tirpate		Acutely Toxic			
Titanium dioxide		IARC list 2B	Prop 65		
Titanium Tetrachloride		EPA Haz list			
Tobacco Smoking (See Tobacco Related Exposures)		KNOWN Carcinogens N	Prop 65		
Tobacco, smokeless		IARC list Group 1	Prop 65		
Tobramycin sulfate		Prop 65			
Toluene		Prop 65			
Toluene 2,4-Diisocyanate		EPA Haz list			
Toluene 2,6-Diisocyanate		EPA Haz list			
Toluene diisocyanates		IARC list 2B	Prop 65	Reasonably Anticipated NTP	
Topiramate		Prop 65			
Toxaphene		Reasonably Anticipated	Prop 65	IARC list 2B	Acutely Toxic
Toxins derived from *Fusarium moniliforme (Fusarium verticillioides)*		Prop 65			
Trans-1,4-Dichlorobutene		EPA Haz list			
trans-2-[(Dimethylamino)methylimino]-5-[2-(5-nitro-2-furyl)-vinyl]-1,3,4-oxadiazole		IARC list 2B	Prop 65		
Treosulfan		IARC list Group 1	Prop 65		
Triadimefon		Prop 65			
Triamiphos		EPA Haz list			
Triamterene		IARC list 2B			
Triazofos		EPA Haz list			
Triazolam		Prop 65			
Tributyltin methacrylate		Prop 65			
Trichlormethine (Trimustine hydrochloride)		IARC list 2B	Prop 65		
Trichloro(Chloromethyl)Silane		EPA Haz list			
Trichloro(Dichlorophenyl) Silane		EPA Haz list			
Trichloroacetic acid		IARC list 2B	Prop 65		
Trichloroacetyl Chloride		EPA Haz list			
Trichloroethylene		KNOWN Carcinogens N	Prop 65	IARC list Group 1	
Trichloroethylsilane		EPA Haz list			
Trichloromethanethiol		Acutely Toxic			
Trichloronate		EPA Haz list			
Trichlorophenylsilane		EPA Haz list			
Trientine hydrochloride		Prop 65			
Triethoxysilane		EPA Haz list			
Triforine		Prop 65			
Trilostane		Prop 65			

TRIM® VX	NA	Prop 65			
Trimethadione		Prop 65			
Trimethyl phosphate		Prop 65			
Trimethylchlorosilane		EPA Haz list			
Trimethylolpropane Phosphite		EPA Haz list			
Trimethyltin Chloride		EPA Haz list			
Trimetrexate glucuronate		Prop 65			
Triamterene		Prop 65	IARC list 2B		
Triphenyltin Chloride		EPA Haz list			
Triphenyltin hydroxide		Prop 65			
Tris(1,3-dichloro-2-propyl) phosphate (TDCPP)		Prop 65			
Tris(1-aziridinyl)phosphine sulfide (Thiotepa)		Prop 65			
tris(2,3-Dibromopropyl) Phosphate		Reasonably Anticipated	Prop 65	IARC list 2A	
Tris(2-chloroethyl) phosphate		Prop 65			
Tris(2-Chloroethyl)Amine		EPA Haz list			
Trp-P-1 (3-Amino-1,4-dimethyl-5H-pyrido[4,3-b]indole)		IARC list 2B	Prop 65		
Trp-P-2 (3-Amino-1-methyl-5H-pyrido[4,3-b]indole)		IARC list 2B	Prop 65		
Trypan blue		IARC list 2B	Prop 65		
Ultraviolet radiation (wavelengths 100-400 nm, encompassing UVA, UVB, and UVC)	NA	IARC list Group 1	KNOWN Carcinogens NTP		
Unleaded gasoline (wholly vaporized)		Prop 65			
Uracil mustard		IARC list Group 2B	Prop 65		
Urethane		Reasonably Anticipated	Prop 65		
Urofollitropin		Prop 65			
Valinomycin		EPA Haz list			
Valproate (Valproic acid)		Prop 65			
Vanadic acid, ammonium salt		Acutely Toxic			
Vanadium pentoxide		IARC list Group 2B	Prop 65	EPA Haz list	Acutely Toxic
Vinblastine sulfate		Prop 65			
Vinclozolin		Prop 65			
Vincristine sulfate		Prop 65			
Vinyl acetate		IARC list Group 2B	EPA Haz list		
Vinyl bromide		IARC list Group 2A	Prop 65	Reasonably Anticipated NTP	
Vinyl Chloride		KNOWN Carcinogens N	Prop 65	IARC list Group 1	
Vinyl cyclohexene dioxide (4-Vinyl-1-cyclohexene diepoxide)		Prop 65			
Vinylidene chloride (1,1-Dichloroethylene)	75-35-4	Prop 65	IARC list Group 2B		
Vinyl fluoride		IARC list Group 2A	Prop 65	Reasonably Anticipated NTP	
Vinyl trichloride (1,1,2-Trichloroethane)		Prop 65			
Vinylamine, N-methyl-N-nitroso-		Acutely Toxic			
Warfarin		EPA Haz list	Prop 65		
Warfarin Sodium		EPA Haz list	Acutely Toxic		
Wood dust		IARC list Group 1	Prop 65	KNOWN Carcinogens NTP	
X-Radiation and Gamma Radiation (See Ionizing Radiation		KNOWN Carcinogens N	IARC list Group 1		
Xylylene Dichloride		EPA Haz list			
Zalcitabine		IARC list Group 2B	Prop 65		
Zidovudine (AZT)		IARC list Group 2B	Prop 65		

Zileuton		Prop 65	
Zinc cyanide		Acutely Toxic	
Zinc Phosphide		EPA Haz list	Acutely Toxic
Zinc, bis(dimethylcarbamodithioato- S,S')-,		Acutely Toxic	
Zinc, Dichloro(4,4-Dimethyl-5((((Methylamino)Carbonyl) Oxy)Imino)Pentanenitrile)-, (T-4)-		EPA Haz list	
Ziram		Acutely Toxic	