Safe Storage of Hazardous Chemicals

General Assistance

Environment, Health & Safety

business hours (510) 642-3073

Emergency Phone Numbers

Life-threatening Emergencies

land line 911
cell phone (510) 642-3333

Hazardous Material Spills

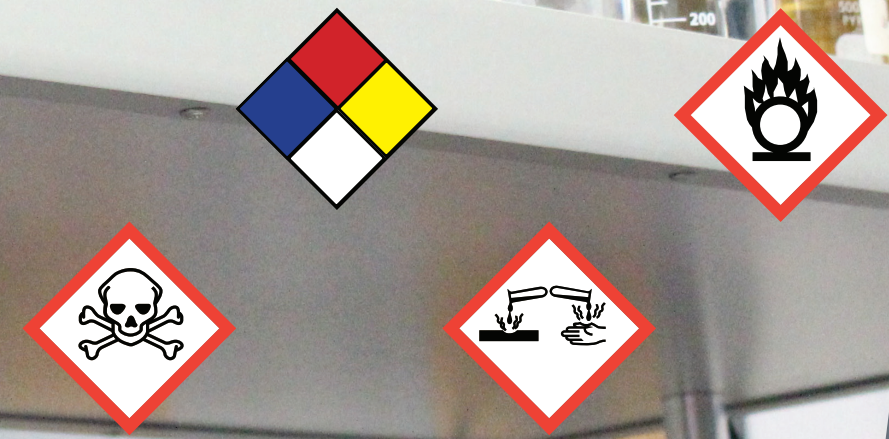
business hours (510) 642-3073 *EH&S*
off-hours & weekends (510) 642-6760 *UCPD*

Facilities Services

24 hour contact (510) 642-3073

Department Contacts

Name	Phone Number
Department Safety Coordinator	
Building Coordinator	
Lab or Shop Emergency Contact	



Office of Environment, Health & Safety
ehs.berkeley.edu

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UNIVERSITY OF CALIFORNIA

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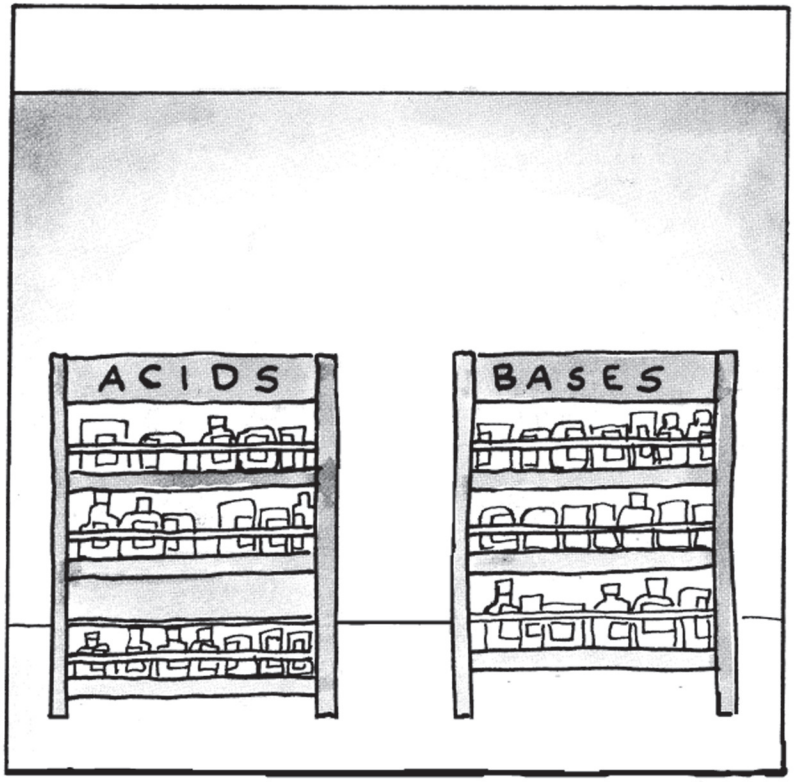


Illustrations by Oruc Cakmakli

Introduction

The safe storage of hazardous chemicals is an essential part of an environmental, health, and safety program. Chemical storage facilities must meet certain minimum standards to satisfy diverse regulations, such as those of Cal/OSHA, the local sanitary district, and the California Fire Code. This manual provides guidelines to help you meet these standards.

In addition, laboratories and work areas on campus must observe several requirements that incorporate safe storage:

- Keeping an up-to-date chemical inventory
- Maintaining a chemical hygiene plan and documenting staff training
- Conducting annual self-inspections

EH&S provides more information on the above programs at its website *http://ehs.berkeley.edu*.

The five sections of this brochure cover the main elements of a safe chemical storage program:

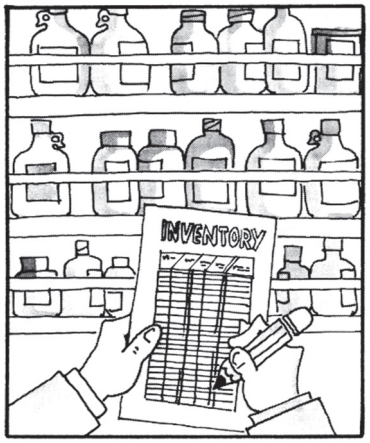
Section	Information
1	How to Maintain an Accurate Inventory of Hazardous Chemicals
2	Proper Chemical Labeling
3	Segregating Incompatible Chemicals
4	Providing Basic Storage Needs
5	Storing Chemicals according to their Hazardous Characteristic

1.0 Take Inventory of Your Chemicals

Safe storage begins with an up-to-date inventory of hazardous chemicals that can be used to apprise personnel of the dangers in a laboratory, shop, or work area. An accurate inventory is also necessary if emergency responders are to respond effectively to a fire or chemical release in the area. The campus can be fined if it does not provide an inventory to emergency response personnel and appropriate regulatory agencies.

The Office of Environment, Health & Safety (EH&S) coordinates the collection of chemical inventories for the campus. Submit your inventory to EH&S annually. Also submit one whenever the maximum amount listed for a particular chemical changes by more than 50 percent or you obtain a chemical that was previously not reported. Immediately notify EH&S if a laboratory or other area has been cleaned out or a new laboratory has started up or moved.

The annual review of your chemical inventory is a prime opportunity to clean out unwanted chemicals. Your unwanted chemicals will either be picked up and disposed of or collected for reuse through the campus Chemical Exchange Program (CHEX). Visit the EH&S web site (*http://ehs.berkeley.edu*) for Fact Sheets about CHEX and disposal of unwanted hazardous materials.



Keep an extra copy of your inventory handy at a central location.

2.0 Label Your Chemicals

All hazardous chemicals must be clearly labeled for the benefit of current users, emergency personnel, and future users. Unknown chemicals can be expensive to dispose of. Make sure all labels are legible and in good condition. Repair or replace damaged or missing labels.

Manufacturers' Labels

Cal/OSHA requires that manufacturers provide labels with the following information:

- contents of the container
- physical and health hazard information
- name, address, and emergency phone number of the manufacturer or other responsible party

Original manufacturers' labels must not be removed or defaced. Material Safety Data Sheets (MSDSs) must be accessible to anyone working with these chemicals. Electronic format MSDSs are available from the EH&S web site at *http://ehs.berkeley.edu*. The MSDS may also provide useful storage information.

Your Own Labels

Hazardous chemicals that are not in the manufacturer's original container (e.g., working solutions prepared in the lab) must, at a minimum, be labeled with the contents of the container. If the contents are hazardous, attach a label indicating the hazard to warn individuals in the work area. It is not necessary to label containers that will be used temporarily (during one work shift) and are under your immediate control.

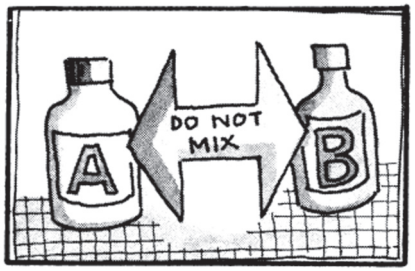
Label your chemicals.

3.0 Segregate Incompatibles

Chemical Families

Materials should always be segregated and stored according to their chemical family or hazard classification. Do not store chemicals alphabetically unless they are compatible! The most common hazard classes include:

- flammables/combustibles
- corrosive acids
- corrosive bases
- toxics
- highly toxics
- oxidizers
- compressed gases
- cryogens
- pyrophorics
- water reactives
- explosives



Accidental contact between incompatible chemicals can result in a fire, an explosion, the formation of highly toxic and/or flammable substances, or other potentially harmful reactions:

> Oxidizers mixed with flammable solvents can cause a fire. Acids mixed with metal dust can produce flammable hydrogen gas.
>
> Alphabetical storage can bring incompatibles together. For example, if chromic acid (an oxidizing acid) and chromium powder (a combustible metal) were stored together and an accident broke their containers, the chemicals could mix and react with explosive violence.

Segregate Families

Each chemical family should be separated from all other chemical families by an approved non-combustible partition or by a distance of twenty feet. Ideally, each hazard class would be kept in a cabinet or on a shelf segregated from other hazard classes. Incompatible chemicals within the same hazard class should also be separated from one another. For example, both nitric and perchloric acids are incompatible with organic acids (such as acetic acid) and should not be stored together.

Most labs have limited space, but the following priorities may help you decide how to store the chemicals.

- Do not store chemicals alphabetically unless they are compatible.
- Store flammable liquids in approved safety containers in flammable storage cabinets. Do not store anything but flammable or combustible liquids in these cabinets.
- Segregate acids from bases.
- Segregate most organic acids from oxidizing mineral acids.
- Keep oxidizers away from other chemicals, especially flammables, combustibles, and toxic materials.
- Keep corrosives away from substances that they may react with and release corrosive, toxic, or flammable vapors.

Multiple Hazard Classes

Many chemicals belong to more than one chemical family or hazard class. In such cases, all storage rules must be strictly observed. For example, acetic acid is both a corrosive acid and a combustible liquid. It must be stored away from corrosive bases, such as sodium hydroxide, and also from oxidizing acids, such as nitric acid.

For More Information

For more specific information, use the storage guidelines that follow. You can obtain labels and material safety data sheets (MSDSs) from the manufacturer, your department, or EH&S. MSDSs provide information on chemical compatibility.

3.1 Common Incompatibles

Do not store incompatible chemicals in close proximity to each other. In an earthquake, fire, or other spill, they could mix and react violently and/or release poisonous gas.

Laboratory Material	Incompatible with
Alkali metals like calcium, potassium, and sodium	water, carbon dioxide, carbon tetrachloride, other chlorinated hydrocarbons
Acetic Acid	chromic acid, nitric acid, hydroxyl-containing compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetone	concentrated sulfuric or nitric acid mixtures
Acetylene	copper (tubing), halogens, silver, mercury, and their compounds
Ammonia, Anhydrous	mercury, halogens, calcium hypochlorite, hydrogen fluoride
Ammonium Nitrate	acids, metal powders, flammable liquids, chlorates, nitrates, sulfur, finely divided organics or combustibles
Aniline	nitric acid, hydrogen peroxide
Bromine	ammonia, acetylene, butadiene, butane, hydrogen, sodium carbide, turpentine, finely divided metals
Chlorates	ammonium salts, acids, metal powders, sulfur, carbon, finely divided organics, combustibles
Chromic Acid	acetic acid, naphthalene, camphor, alcohol, glycerine, turpentine, other flammable liquids or combustible materials

Chlorine	ammonia, acetylene, butadiene, benzene, other petroleum fractions, hydrogen, sodium carbide, turpentine, finely divided powdered metals
Cyanides	acids
Hydrogen Peroxide	copper, chromium, iron, most metals or their respective salts, flammable liquids or combustible materials, aniline, nitro-methane
Hydrogen Sulfide	nitric acid, oxidizing gases
Hydrocarbons (general)	halogens, chromic acid, sodium peroxide
Iodine	acetylene, ammonia, chlorine
Mercury	acetylene, ammonia, lithium
Nitric Acid	acetic, chromic, and hydrocyanic acids, aniline, carbon, hydrogen sulfide, flammable material, readily nitrated substances
Oxygen	oils, grease, hydrogen; flammable materials
Oxalic Acid	silver, mercury, chlorites, strong oxidizers
Perchloric Acid	acetic anhydride, bismuth and its alloys, alcohol, paper, wood, other organic materials
Potassium Permanganate	glycerine, ethylene glycol, benzaldehyde, sulfuric acid
Sodium Peroxide	any oxidizable substances
Sulfuric Acid	chlorates, perchlorates, permanganates

4.0 Basic Storage Requirements

The following basic storage requirements apply to all hazardous chemicals. Refer to the "Chemical Storage Guide" sections of this brochure for additional requirements that apply to chemicals in a specific hazard class (e.g., flammables and corrosives).

Storage Area Requirements

✔ Label storage areas according to the type of chemical family or hazard classification found there.

✔ Inspect storage areas at least annually, as required by Cal/OSHA.

✔ Keep aisles, hallways, doorways, exits, and entryways clear.

✔ Keep storage areas well lit, appropriately ventilated, and at a consistent, cool temperature.

✔ Eliminate ignition sources such as open flames, heat sources, or direct sunlight.

✔ Keep emergency equipment such as fire extinguishers handy and in good working order.

✔ Confine chemical storage areas so that leaks or spills are controlled. Prevent chemicals from running down sink, floor, or storm water drains. Clean up spills and drips immediately.

Storage Don'ts

✖ Don't store chemicals in a sink or fume hood, except for certain toxic gases that are so dangerous they can only be stored in a gas cabinet or fume hood.

✖ Don't store chemicals on dirt or grass, near a creek or storm drain entrance, where they could contaminate the environment.

✖ Don't store chemicals on the floor, window ledges, or balconies.

Storage Cabinets

Use only approved storage cabinets. Never alter a flammable storage cabinet unless directed to do so by EH&S.

Label cabinets with the hazard class of the chemicals.

Storage Shelves

Shelves should be level, stable, and secured to the wall or another stable surface.

In case of an earthquake, shelves should have raised edges or rim guards (minimum height of 2 inches) to prevent containers from falling. Use bungee cords for added security.

Shelves should be kept free of chemical contamination and dust.

Shelves should be located away from direct sun, flame, and heat sources.

Containers should not protrude over shelf edges.

Store large bottles/containers no higher than 2 feet from the floor. Store corrosives on lower shelves.

Storage Containers

Keep containers closed unless you are dispensing a chemical or adding to the container. Never store a container open with a funnel in it.

Provide secondary containment for liquids in containers larger than 1 gallon in size. Dishpans or polyethylene trays work well.

Use approved containers for flammable solvents.

5.0 Chemical Storage Guide: Individual Hazards and Mixed Hazards

Sections 5.1 through 5.11 provide basic storage guidelines for the most common hazard classes. Each section describes the characteristics of the hazard class (consistent with California Fire Code). It includes common examples of laboratory and non-laboratory chemicals and provides basic storage requirements and precautions. Note: These examples do not constitute a full list, and the laboratory/non-laboratory classifications may not strictly apply.

Please note that many chemicals have multiple hazard classifications. Consequently, you may need to consult several storage guideline sections to determine how to store a hazardous chemical safely. For example, acetic acid is a corrosive acid and also a combustible liquid. Therefore, you need to follow section 5.1 (flammables and combustibles) and section 5.2 (corrosives). You may also call EH&S for help.

Federal and state regulations may require a Risk Management Plan for certain highly hazardous chemicals, depending on the amount stored. EH&S periodically reviews your chemical inventory and will notify you if there is a concern. It is a prudent practice to maintain the lowest possible quantities of highly hazardous chemicals.

The capital letters in parenthesis used in sections 5.1– 5.11 that follow the chemical examples indicate that the chemical has an additional hazardous characteristic other than the one being discussed. Refer to the appropriate storage guideline section in this brochure for information and follow its directives as well.

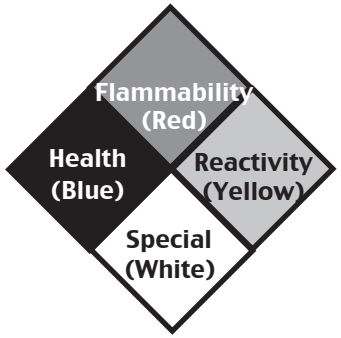
NFPA Chemical Hazard Identification System

Each hazard class section on the following pages includes two chemical examples illustrated with National Fire Protection Association (NFPA) diamond symbols that rate the degree of health, flammability, reactivity, and special hazards of the

chemicals discussed. Hazards are rated from 0 for minimal hazard to 4 for severe hazard.

The degree of hazard is often dependent upon the physical state of the chemical as well. For example, a flammable gas will pose a more significant immediate safety threat upon release than a liquid that has the same flash point.

The NFPA Health Hazard rates the effect of short-term exposure to a chemical by physical contact, eye and skin absorption, or inhalation. A highly toxic chemical with a health hazard rating of 4 could be lethal on very short exposure.



The NFPA Flammability Hazard rates the ease with which a chemical will ignite from exposure to a spark, open flame, or high temperature. A flammable or pyrophoric chemical with a flammability rating of 4 could readily ignite at room temperature.

The NFPA Reactivity Hazard rates a chemical's thermal instability, potential for hazardous reaction with water, or sensitivity to friction or shock. A highly unstable chemical, such as an explosive with a reactivity rating of 4, could readily detonate if exposed to localized thermal or mechanical shock at normal temperatures and pressures.

The NFPA Special Hazards include W (to indicate a water reactive chemical that could react violently or explosively upon contact with water) and OX (to indicate an oxidizer that could ignite combustible or flammable material upon contact).

5.1 Flammables and Combustibles

Characteristics

These chemicals are easily ignited and may present a serious fire and explosion hazard. Flammable liquids have a flash point below 100°F. Combustible liquids have a flash point of 100°F to 200°F. Flammable solids have an ignition temperature below 212°F. Flammable solids include finely divided solid materials which, when dispersed in air, could ignite. Other classes of chemicals with a high fire hazard include oxidizers (section 5.5), pyrophoric chemicals (section 5.8), and water reactive chemicals (section 5.9).

Laboratory Chemicals

Flammable Solids

naphthalene (HT)
finely divided metal (e.g., aluminum, cadmium, chromium, titanium, zinc) (P)

Flammable Liquids

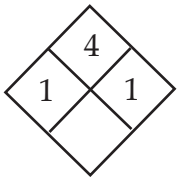
alcohols - methanol, ethanol
esters - ethyl acetate
ethers - diethyl ether
ketones - acetone, cyclohexane

Flammable Gases

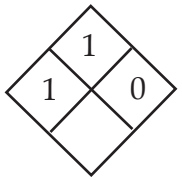
hydrogen
methane

Combustible Liquids

acetic acid (CA)
cumene
phenol (CA, T)
propionic acid (CA)



ethyl ether



glycerine

Non-Laboratory Chemicals

Flammable Solids

moth balls (HT)
(containing naphthalene)
calcium carbide (WR)

Flammable Liquids

gasoline
lighter fluid
paint thinner

Flammable Gases

acetylene

Combustible Liquids

antifreeze
diesel fuel
engine oil

Additional hazardous characteristics: CA–Corrosive acid; HT–Highly toxic; P–Pyrophoric; T–Toxic; WR–Water reactive

Storage Limits

California Fire Code regulations limit the quantity of flammable liquids stored in research and teaching laboratories on the Berkeley campus.

Quantity Limits outside Flammable Storage Cabinets
A maximum of ten (10) gallons of flammable liquids may be stored outside a flammable storage cabinet.

Quantity Limits within Flammable Storage Cabinets
Flammable liquids stored in approved cabinets within laboratories or classrooms shall not exceed sixty (60) gallons.

Maximum Container Capacity
- The capacity of glass containers shall not exceed one (1) gallon.
- The capacity of all other containers (including safety cans) shall not exceed two (2) gallons.

See the Fact Sheet on the storage of flammable liquids at *http://ehs.berkeley.edu*. If you need additional information, please contact the Campus Fire Marshal at 642-4409.

Storage Precautions for Flammables and Combustibles

Keep flammables away from all ignition sources: open flames, hot surfaces, direct sunlight, spark sources.

Store flammables separate from other hazard classes, especially oxidizers and toxics.

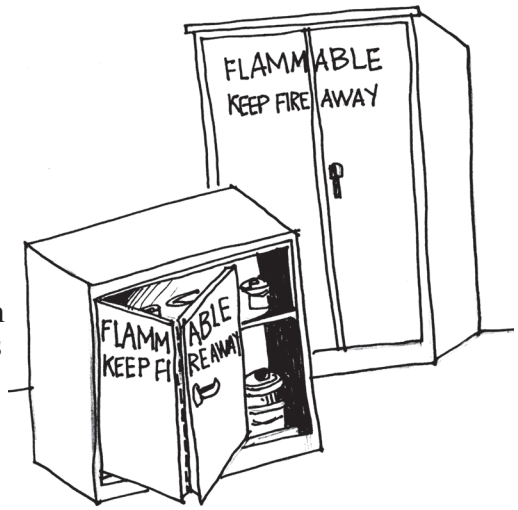
Separate flammable gases from oxidizing gases with an approved non-combustible partition or by a distance of 20 feet.

Store flammable liquids in approved safety containers or cabinets.

In instances where static electricity may accumulate and ignite flammable vapors, ground and bond flammable liquid containers.

Keep a fire extinguisher (appropriate for the hazard) readily available and make sure anyone who may need to use it is properly trained.

Keep flammable liquids that require cold storage in laboratory-safe flammable material refrigerators or freezers to avoid ignition of the materials by sparks or static electricity. See the Fact Sheet about storage of hazardous materials in freezers and refrigerators at *http://ehs.berkeley.edu.*



Retrofitting non-laboratory safe refrigerators for use with flammables is prohibited.

5.2 Corrosives

Characteristics

Strong acids and bases can destroy human tissue and corrode metals. Acids and bases are incompatible with one another and may react with many other hazard classes.

Laboratory Chemicals

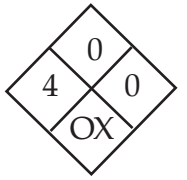
Acids

Organic Acids

acetic acid (C)
citric acid (C)
formic acid (C, T)
oxalic acid (T)

Inorganic Oxidizing Acids

chromic acid (O, T)
nitric acid (HT, O)
perchloric acid (O, PEC)
sulfuric acid (O, T, WR)



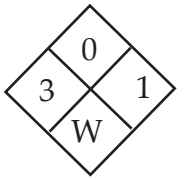
nitric acid

Inorganic Non-Oxidizing Acids

hydrochloric acid
phosphoric acid

Bases

ammmonium hydroxide (T)
calcium hydroxide
potassium hydroxide (T, WR)
sodium hydroxide (T, WR)
tri-sodium phosphate (T)



sodium hydroxide

Non-Laboratory Chemicals

Acids

muriatic acid (contains hydrochloric acid)

Bases

drain declogger (containing sodium hydroxide)
wall cleaner (containing tri-sodium phosphate)

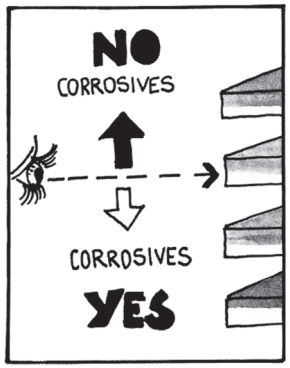
Additional hazardous characteristics: C–Combustible liquid or solid; HT–Highly toxic; O–Oxidizer; PEC–Potentially explosive chemical; T–Toxic; WR–Water reactive

Storage Precautions for Corrosives

Segregate acids from bases. Segregate inorganic oxidizing acids (e.g., nitric acid) from organic acids (e.g., acetic acid), flammables, and combustibles.

Segregate acids from chemicals that could generate toxic gases upon contact (e.g., sodium cyanide and iron sulfide).

Segregate acids from water reactive metals such as sodium, potassium, and magnesium.



Use tight-fitting goggles, gloves, and closed-toe shoes while handling corrosives.

Store solutions of inorganic hydroxides in polyethylene containers.

Store corrosives on lower shelves, at least below eye level and in compatible secondary containers.

Do not store corrosives on metal shelves. Although ventilation helps, chemicals will still corrode the shelves. Store containers in plastic tubs or trays as secondary containment.

If you notice powder deposits, discoloration, and crystallization around the cap of a container, particularly an oxidizing acid, contact EH&S immediately. The material may be potentially explosive.

Follow the special handling and use procedures for hydrofluoric acid (See the Fact Sheet about hydrofluoric acid at *http://ehs.berkeley.edu*). Keep calcium gluconate available as an antidote.

Have spill control pillows or neutralizing agents available in case of a spill. These may be purchased from safety supply companies.

5.3 Toxics

Characteristics

Overexposure to toxic chemicals can cause injury or death. Toxics are chemi-cals with a lethal dose (LD50) of more than 50 and less than 500 milligrams per kilogram body weight or a lethal concentration (LC50) in air of more than 200 and less than 1,000 parts per million.

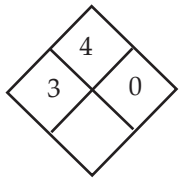
Laboratory Chemicals

Solids	**Liquids**	**Gases**
acrylamide	aniline (C)	ammonia
cadmium chloride	chlordane	hydrogen fluoride (CA)
potassium fluoride (CA)	phenol (C, CA)	vinyl bromide

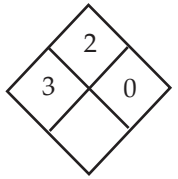
Non-Laboratory Chemicals

Solids	**Liquids**
diazinion	copper sulfate

Additional hazardous characteristics:
C - Combustible liquid; CA - Corrosive Acid



hydrogen sulfide



phenol

Storage Precautions for Toxics

Segregate toxics from other hazard classes and store in a cool, well ventilated area, away from light and heat.

Containers should be tightly sealed to minimize exposure to personnel and contamination of other chemicals.

Manage toxic gases, highly toxic gases, and pyrophoric gases in accordance with the campus Toxic Gas Program requirements. Contact EH&S for specifics, or print out the Fact Sheet about the campus Toxic Gas Program at *http://ehs.berkeley.edu*.

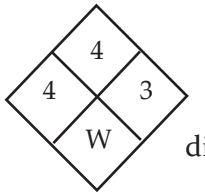
5.4 Highly Toxics

Characteristics

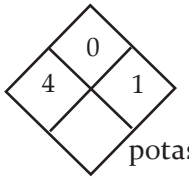
These chemicals can cause serious injury or death at low concentrations. Highly toxics are chemicals with a lethal dose (LD50) of less than or equal to 50 milligrams per kilogram body weight or a lethal concentration (LC50) in air of less than or equal to 200 parts per million.

Laboratory Chemicals

Solids	**Liquids**	**Gases**
arsenic salts	acrolein	diborane (P, WR)
calium cyanide	hydrocyanic acid (CA, F)	fluorine (CA, O, WR)
organic mercury compounds	nicotine (C)	nitrogen dioxide (O)



diborane



potassium dichromate

Additional hazardous characteristics: C–Combustible; CA–Corrosive acid; F–Flammable; O–Oxidizer; P–Pyrophoric; WR–Water reactive

Storage Precautions for Highly Toxics

Maintain the lowest possible quantities of highly toxics.

Segregate highly toxic chemicals from other hazard classes and store in an area that is cool, well ventilated, and away from light and heat.

Use highly toxic chemicals in a designated area or laboratory. Highly toxic chemicals that produce fumes or dust should always be handled within a chemical fume hood.

The California Fire Code limits the aggregate amount of highly toxic solids and liquids to 10 pounds per laboratory or storage area.

The California Fire Code limits the amount of highly toxic gases to 20 cubic feet per laboratory or storage area.

Manage toxic gases, highly toxic gases, or pyrophoric gases in accordance with the campus Toxic Gas Program requirements. See the Fact Sheet about the campus Toxic Gas Program at *http://ehs.berkeley.edu*. Contact EH&S for specifics.

Containers should be tightly sealed to minimize exposure to personnel and avoid contamination from other chemicals.

Do not eat, drink, or apply cosmetrics where highly toxic chemicals are handled.

Handle highly toxic chemicals in a chemical fume hood.

5.5 Oxidizers

Characteristics

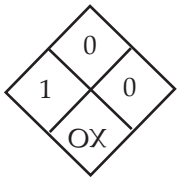
Oxidizers are a fire hazard. They will readily decompose under certain conditions to yield oxygen or react to promote or initiate the combustion of flammable or combustible materials.

Laboratory Chemicals

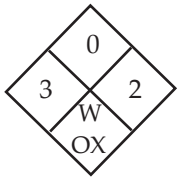
Solids	Liquids	Gases
ammonium nitrate	bromine	chlorine (HT)
calcium nitrate (T)	chromic acid (CA, T)	fluorine (CA, HT, WR)
potassium chlorate	hydrogen peroxide	nitrogen dioxide (HT)
potassium nitrate	nitric acid (CA, HT)	oxygen
sodium dichromate (H, T)	perchloric acid (CA, PEC)	ozone (H, T)
sodium nitrate	sulfuric acid (CA, T, WR)	

Non-Laboratory Chemicals

Solids	Liquids	Gases
fertilizers (e.g., ammonium nitrate)	bleaching agents (e.g., hyrogen peroxide, sodium hypochlorite)	oxygen
pool chemicals (e.g., bromine tablets)		chlorine (T)



silver nitrate



sulfuric acid

Additional hazardous characteristics: CA–Corrosive acid; T–Toxic; HT–Highly toxic; PEC–Potentially explosive chemical; WR–Water reactive

Storage Precautions for Oxidizers

Segregate oxidizers from flammable and combustible materials (paper, wood). See Flammables and Combustibles (section 5.1).

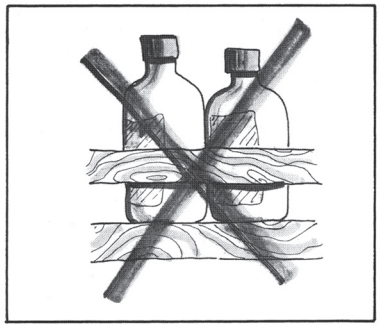
Segregate oxidizers from reducing agents (zinc, alkaline metals, formic acid).

Segregate inorganic oxidizers from organic peroxides.

Take care not to contaminate oxidizers. Some oxidizers, such as perchloric acid, can become explosive mixtures if contaminated with trace amounts of organic materials or metals. See Explosive and Potentially Explosive Chemicals (section 5.10).

Store in a cool, dry place. Do not store under sink.

Remember that perchloric acid, nitric acid, and hydrogen peroxide are oxidizers and must not be stored on wooden shelves or in cardboard boxes.



Do not store oxidizers on wood shelves. A leak could start a fire.

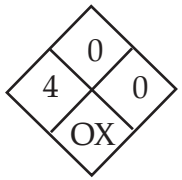
5.6 Compressed Gases

Characteristics

What all compressed gases have in common is the large amount of energy stored in the cylinder from the compression of the gas. Dropping or knocking over a cylinder can cause the energy to be rapidly released. It may even propel a cylinder like a rocket. Additional hazards can arise from the toxicity, flammability, corrosivity, or reactivity of the gas.

Laboratory Chemicals

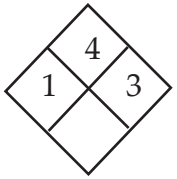
argon
butane (F)
carbon monoxide (T)
chlorine (T,O)
ethylene (F)
hydrogen (F)
methane (F)
nitrogen



chlorine

Non-Laboratory Chemicals

acetylene (F)
compressed air
oxygen (O)



acetylene

Additional hazardous characteristics:
F–Flammable; T–Toxic; O–Oxidizer

Storage Precautions for Compressed Gases

Segregate incompatible gases as you would other incompatible chemicals.

Limit the quantity of compressed gas cylinders on site to what will be used within a reasonable period of time.

Store cylinders upright.

Secure cyclinders so they will not fall during an earthquake.

An acceptable means includes using two non-combustible restraints, such as chains, one restraint located approximately one-third of the cylinder length from the top, and the other restraint one-third from the bottom.

Keep cylinders away from heat and open flames.

Leave the valve protection cap on the cylinder unless it is in use.

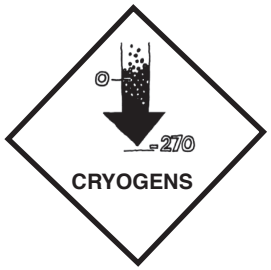
Never store cylinders in walk-in freezers. The confined space with no ventilation poses a potential hazard.

If you suspect that a cylinder is leaking, do not attempt to sniff the leak out. Apply a soap solution to the cylinder and locate the leak by noting where the bubbles appear.

Toxic gases, highly toxic gases, and pyrophoric gases must be managed in accordance with the campus toxic gas program requirements. See the Fact Sheet about the campus Toxic Gas Program at *http://ehs.berkeley.edu*. Contact EH&S for details about ventilation and quantity limitations.

Secure gas cylinders adequately.

5.7 Cryogens

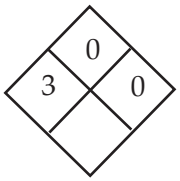


Characteristics

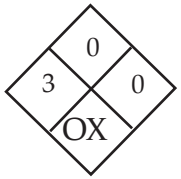
These materials are extremely cold (-100°C to -270°C). Upon contact with cryogenic materials, living tissue can freeze and become brittle enough to shatter. Additional hazards include rapid pressure buildup, oxygen enrichment, and asphyxiation. Rapid pressure buildup could lead to an explosion if cryogen is improperly contained. Cryogenic liquids and gases have many properties and hazardous characteristics in common with compressed gases.

Laboratory Chemicals

liquid argon
liquid carbon monoxide (F, T)
liquid ethylene (F)
liquid fluorine (CA, HT, O, WR)
liquid helium
liquid hydrogen (F)
liquid methane (F)
liquid nitrogen
liquid oxygen (O)



liquid nitrogen



liquid oxygen

Additional hazardous characteristics: CA–Corrosive acid; F–Flammable; HT–Highly toxic; O–Oxidizer; T–Toxic; WR–Water reactive

Storage Precautions for Cryogens

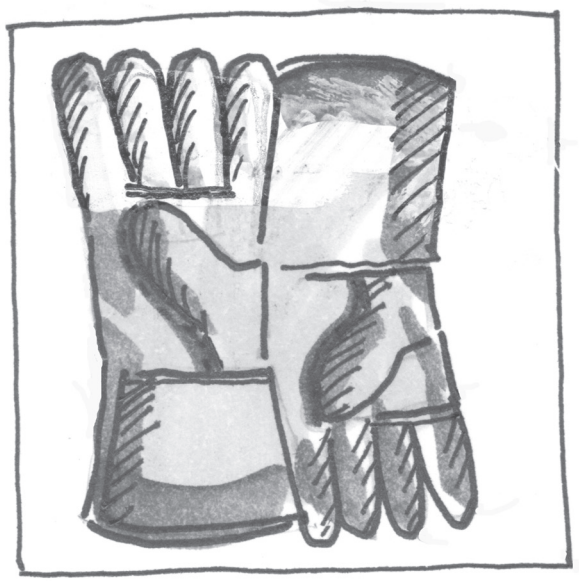
Store and handle in a well-ventilated area. When liquid cryogens are converted to the gaseous phase, they may create an oxygen deficiency. Do not use cryogens in small enclosed spaces.

Use only approved storage vessels (i.e., thermos-like evacuated, double-walled containers) with pressure relief mechanisms. Non-approved vessels may explode.

Secure containers so they will not tip over or obstruct an aisle, hallway, or corridor during an earthquake.

Liquid nitrogen and liquid helium are capable of liquefying oxygen from air. This form of oxygen enrichment can become a strong fire or explosion hazard.

Use appropriate protective equipment for handling cryogens: insulated holders for carrying vessels; eye protection, goggles, or face shields; and aprons. Use cryogenic gloves or leather gloves when handling supercold surfaces.



Wear cryogenic or leather gloves when handling supercold surfaces.

5.8 Pyrophorics (Air Reactives)

Characteristics

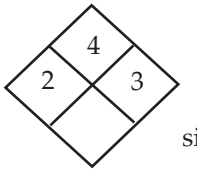
Substances that ignite spontaneously upon contact with air.

Laboratory Chemicals

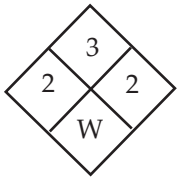
Solids
sodium (WR)
finely divided metal (e.g., aluminum, chromium, zinc)

Liquid
aluminum borohydride (CB,WR)
diethylzinc (WR)

Gases
diborane (HT, WR)
phosphine (HT, WR)
silane (WR)



silane



zinc

Storage Precautions for Pyrophorics

Store in a cool, dry place. Prevent contact with air.

Take extreme care to prevent containers of pyrophorics from leaking or breaking. The use of corrosion- and shatter-resistant secondary containers for storage and transportation of pyrophoric reagent bottles is encouraged.

Many pyrophorics are also water reactives (section 5.9).

Manage pyrophoric gases, toxic gases, and highly toxic gases, in accordance with the campus Toxic Gas Program requirements. See the Fact Sheet about the campus Toxic Gas Program at *http://ehs.berkeley.edu*. Contact EH&S for specifics.

5.9 Water Reactives

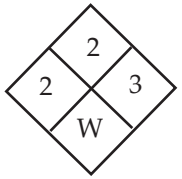
Characteristics

These substances often react violently with water and may ignite or generate toxic, flammable, or corrosive gases.

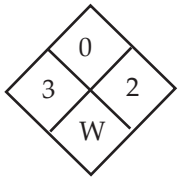
Laboratory Chemicals

Solids
aluminum chloride (anhydrous)
calcium carbide (F)
magnesium (F)
phosphorus pentatchloride (CA, HT)
sodium (P)

Liquids
acetyl chloride (CA, F)
chlorosulfonic acid (CA, HT)
stannic chloride (CA)
thionyl chloride (CA)



antimony



potassium hydroxide

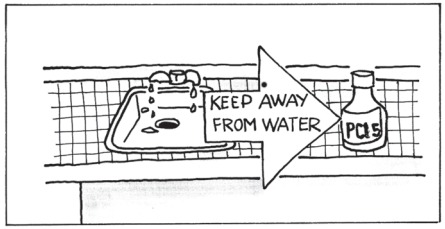
Additional hazardous characteristics: CA–Corrosive acid; F–Flammable; HT–Highly toxic; P–Pyrophoric

Storage Precautions for Water Reactives

Store in a cool, dry place.

Keep away from water.

In case of fire, do not use water. Use a dry chemical extinguisher.



Keep water reactives in a dry environment.

5.10 Explosive and Potentially Explosive Chemicals

Characteristics

Explosive chemicals can rapidly release tremendous amounts of destructive energy. Explosive chemicals can cause death, serious injury, or severe property damage. Heat, shock, friction, or even static electricity can initiate explosions of these chemicals. The family includes pure chemicals (e.g., TNT) and mixtures (e.g., ammonium nitrate/ fuel mixtures).

In addition to explosive chemicals, which constitute a known high hazard, there are chemicals that may become explosive, depending on how they are handled. This category is commonly referred to as potentially explosive chemicals and includes:

- pure chemicals or mixtures that may become explosive through contamination (e.g., perchloric acid contaminated with organic compounds or metals); and

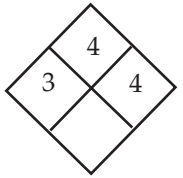
- pure chemicals or mixtures that may degrade over time and become explosive (e.g., hydrated picric acid, which becomes explosive upon drying). This category also includes certain alcohols and ethers that may accumulate explosive levels of peroxides by interacting with air. See Peroxide Forming Chemicals (section 5.11).

For more extensive information regarding potentially explosive chemicals, please see the "Guidelines for Explosive and Potentially Explosive Chemicals Safe Storage and Handling" available through the EH&S office or visit the web site: *http://ehs.berkeley.edu*.

Primary Classes of Explosive Chemicals (with examples)

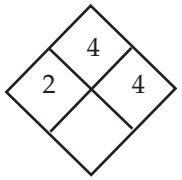
Nitrogen-Oxygen Chemicals
(e.g., Nitrates, Nitro)
ethylidene dinitrate
picric acid (dry)
thallium aci-phenylnitromethanide
trinitrotoluene (TNT)

Oxides, Peroxides, and Related Chemicals
(See **Peroxide Forming Chemicals)**
benzoyl peroxide (97%) (dry)
bis (1-chloroethylthallium chloride) oxide



picric acid (dry)

Nitrogen-Rich Chemicals
(e.g., Azo-, Diazo, Triazo, Tetrazole)
aluminum azide
5-aminotetrazole
1-bromoaziridine
chromyl azide chloride
diethyl diazomalonate
hydrogen azide (>17%)
lead azide
mercury (I&II) azide
molybdenum diazide tetrachloride
sodium diazomethanide
tetrazole
1,2,3-triazole



trinitrotoluene

Perchlorate Chemicals
ammonium perchlorate
ethyl perchlorate (the most explosive chemical known)
hexyl perchlorate

Acetylenic Chemicals
n-chloro-3-aminopropyne
propiolic acid
3-propynethiol
4-sodium hexakis(propynyl)ferrate

Examples of Potentially Explosive Chemicals (which are normally stable)

- Organic chemicals, such as ethers, that form peroxides through exposure to air or light (See Peroxide Forming Chemicals, section 5.11.)
- Hydrated picric acid that becomes dry
- Sodium amide that reacts with air or moisture
- Certain alkyl nitrates (e.g., butyl nitrate or propyl nitrate) that become contaminated with nitrogen oxides
- Certain normally stable perchlorates (e.g., pyridinium perchlorate or tetraethylammonium perchlorate) that become unstable at elevated temperatures

Storage Precautions for Explosive and Potentially Explosive Chemicals

Identify all explosive and potentially explosive chemicals in your inventory.

For chemicals that may degrade to become potentially explosive, record the opening date and discard date directly onto the container or onto a potentially explosive chemical warning label (available from EH&S).

Keep explosive chemicals away from all ignition sources: open flames, hot surfaces, direct sunlight, spark sources.

Store explosive chemicals in an explosive magazine and inspect areas weekly to comply with the California Fire Code. (Contact EH&S for assistance.)

Consider designating a special area to store and use potentially explosive chemicals.

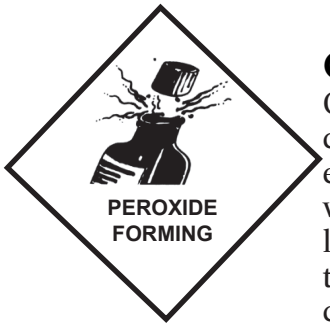
Make sure everyone who uses explosive or potentially explosive chemicals is thoroughly trained in safe storage methods, conditions to avoid (e.g., contamination), the hazards of the chemical, and disposal procedures.

Contact EH&S immediately if you suspect a material may have become explosive. Post warning signs so others do not handle or disturb the material.

Note: Most explosions occur while purifying or distilling mixtures. Therefore, use extreme caution before concentrating or purifying any mixture that may contain an explosive chemical (e.g., a peroxide forming chemical or perchlorate).

Contact EH&S to discuss your storage and handling of explosive and potentially explosive chemicals.

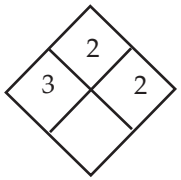
5.11 Peroxide Forming Chemicals



Characteristics

Over a period of time, these chemicals can form peroxides that may explode when the cap is removed or when they are concentrated during laboratory activities. It is important to note on the container the date the chemical arrived in the laboratory, when it was opened, when it should be tested for peroxide concentration, and when it should be discarded. Dispose of the chemical before the discard date indicated on the container or follow the guidelines below.

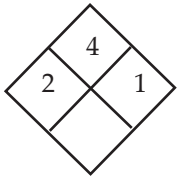
Dispose of within 24 Hours:
acrylic acid (uninhibited)
butadiene (uninhibited)



acrylic acid

Test or Dispose of within 3 Months:
butadiene (inhibited)
chloroprene
divinylacetylene
isopropyl ether

Test or Dispose of within 12 Months:
acetaldehyde
acrolein
benzyl ether
2-butanol
cyclohexanol
diethyl ether
ethyl vinyl ether
2-hexanol
3-methyl-1-butanol
tetrahydrofuran



diethyl ether

Storage and Disposal of Peroxide Forming Chemicals

By the expiration date, the owner/user should either dispose of the chemical or test it for peroxide content. Dispose of any chemicals found to have a peroxide concentration greater than or equal to 100 parts per million. (Call EH&S for assistance.) Materials that have lasted beyond the recommended shelf life but have been tested and show no detectable peroxides, or whose peroxide concentrations are less than 100 ppm, may be retained but should be tested at frequent intervals. **Test all peroxide forming chemicals prior to distillation,** regardless of age.

Important note: Never test containers of unknown age or origin. Old bottles are likely to contain concentrated peroxides, and peroxides may have crystallized in the cap threads, which can present a serious hazard when the bottle is opened for testing.

Contact EH&S for help with managing older containers and for additional guidelines on the safe storage and handling of peroxide forming chemicals.

Storage Precautions for Peroxide Forming Chemicals

Identify all peroxide forming chemicals in your inventory.

Write the opening date and discard date on the containers of chemicals that may degrade to become potentially explosive.

Store in airtight containers in a dark, cool, and dry place.

Never store peroxide formers in a freezer because a change from a solid to a liquid can cause detonation.

Discard or test peroxide forming chemicals before the expiration date printed on the container label. Contact EH&S for disposal information.

If precipitate appears in an organic chemical that may form an explosive peroxide (e.g., crystals around the neck or cap of bottle), or if an oily layer appears, do not move it. Contact EH&S immediately.

Inspect peroxide forming chemicals often for evidence of contamination, degradation, or any change from normal physical or chemical characteristics. Contact EH&S immediately if you suspect a material may have become explosive. Post warning signs so others do not handle or disturb the material.

Note: Most explosions occur while purifying or distilling mixtures. Therefore, use extreme caution before concentrating or purifying any mixture that may contain an explosive chemical (e.g., a peroxide or perchlorate).

For more extensive information regarding potentially explosive chemicals, please see the "Guidelines for Explosive and Potentially Explosive Chemicals Safe Storage and Handling" available through the EH&S office or visit the web site: *http://ehs.berkeley.edu*.

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