

CHAPTER 19 – CHEMICAL HANDLING AND STORAGE

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CHAPTER 19 – CHEMICAL HANDLING AND STORAGE

A. INTRODUCTION

1. This Chapter is applicable to all Smithsonian Institution (SI) facilities and operations. It states general requirements for the safe handling and storage of chemicals unless superseded by specific requirements of other Operational Chapters in this *Manual*.
2. The safe handling and storage of chemicals can be effectively managed through a program of:
 - a. Inventory control,
 - b. Labeling,
 - c. Safe work practices,
 - d. Secondary containment and spill response,
 - e. Storage by compatible classes and in appropriate cabinets, and
 - f. Special controls for highly hazardous substances.

B. CHAPTER-SPECIFIC ROLES AND RESPONSIBILITIES

1. Safety Coordinators, supervisors and employees shall ensure that the handling and storage of chemicals in their facilities and operations adhere to the requirements of this Chapter.
2. The Office of Safety, Health and Environmental Management (OSHEM) shall provide technical assistance, upon request, to Safety Coordinators, supervisors and employees in carrying out their responsibilities under this Chapter.

C. INVENTORY CONTROL

1. Chemicals are to be purchased only in the quantities needed and in containers of the smallest practical size. Although the cost may be higher, significant savings will be gained by reduced hazardous waste disposal or clean up costs.
2. Chemical containers should be plastic bottles, or shatter-resistant plastic coated glass bottles, whenever possible. Glass containers should be avoided to reduce the risk of spills when dropped or damaged.
3. Chemicals shall be inventoried at least annually and excess stocks are to be shared or distributed to other departments to minimize waste. All unused and

outdated chemicals shall be disposed through the SI hazardous waste program, Chapter 29, "Hazardous Waste Management", of this *Manual*.

4. Products that could also be purchased for home use, such as soap, oil, or cleaning sprays, must be part of the chemical inventory and have an MSDS on file if the product will be used in an occupational setting and could cause a health exposure in the workplace.
5. Before a staff member or visiting researcher leaves the SI, all excess chemicals are to be inventoried and distributed or disposed.

D. LABELING

1. All bottles, containers, and other apparatus containing chemicals shall be accurately and clearly labeled as to contents, hazards, and where practical, the appropriate precautions required when handling the chemical. Labels on chemical containers are not to be removed or altered, particularly the manufacturer's original label. Empty chemical containers must never be reused for another purpose, even if the labeling is changed. Reactions with new liquid and residual chemical could be extremely dangerous.
2. In addition, peroxide-forming compounds must be labeled as to the date of receipt by the lab and the date of opening.
3. There are three levels of complexity to labeling: original container, secondary transfer containers, and small container (vials, flask, and beakers) for immediate, same-day use. The labels should serve as backup to hazard communication training.
 - a. The manufacturer's original labels must contain the required OSHA information:
 - (1) Name of chemical or solution;
 - (2) Manufacturer name and emergency telephone number;
 - (3) Hazard warning (health effect or target organs).
 - b. For laboratory-prepared solutions and/or when chemicals are transferred to secondary containers not intended for immediate use, labels should include:
 - (1) Name (no abbreviations) of the chemical and its concentration.
 - (2) For prepared solutions: date prepared, hazard warning on the most serious health or safety hazard posed (consult MSDS). Stickers can be applied indicating "corrosive," "carcinogen," "water-reactive", "flammable", etc. If space allows, or if special precautions are critical, expand the hazard warning to include the target organ and the required protection (e.g. "Corrosive, esp. to skin and eyes. Use gloves and goggles").

- c. Containers for immediate (same day) use should be labeled with the Chemical name and its concentration.

E. SAFE HANDLING AND TRANSFER

1. Transport of chemicals within the facility must be conducted with methods and materials that prevent the risk of breakage. Hand carried chemicals should be placed in unbreakable secondary containers such as bottle carriers or acid-carrying buckets. Wheeled carts used to transport chemicals should have side guards and lipped surfaces capable of containing a break, and sturdy wheels that move easily over uneven surfaces. DOT shipping containers make excellent secondary containment for transport across the building.
2. Staff are to have available protective aprons, gloves, and goggles when transporting chemicals.
3. Freight-only elevators are to be used for transport. Passenger elevators can be used ONLY if the elevator use is temporarily restricted to chemical transport.
4. Class I flammable liquids (any liquid having a flash point below 100°F) shall not be stored or transferred from one vessel to another in an exit access corridor, open plan building, or ancillary spaces unprotected from the exit access corridor.
5. Transfer of Class I liquids to smaller containers from bulk stock containers not exceeding 5 gallons in capacity shall be performed in a laboratory hood, in an area provided with ventilation adequate to prevent accumulations of flammable vapor exceeding 25% of the lower flammable limit, or within an inside liquid storage area approved for dispensing.
6. Class I liquids shall not be transferred between conductive containers of greater than 1.1 gallons, unless the containers are bonded and grounded (the process of providing an electrically conductive pathway - usually by clipping connecting wires - between a dispensing container and a receiving container [bonding], and the receiving container and an earth ground).
7. Transport between facilities. To the extent possible, chemicals (including fluid-preserved collections containers) used by SI employees for SI operations should be transported using SI vehicles only.
 - a. All transport of chemicals between facilities shall be approved by the employee's supervisor as part of official duties.
 - b. Transport of chemicals in privately owned vehicles should be limited.
 - c. If chemicals must be transported, the driver must:
 - (1) Ensure that all containers are secured in the vehicle (e.g., bed of a pickup truck).

- (2) Transport chemicals in their original containers, as practical. Keep containers tightly closed to prevent spills.
 - (3) Have a copy of the MSDS for the chemical.
 - (4) Never transport chemicals in the passenger compartment of a vehicle or in an area where food is being transported.
 - (5) Load containers so as to prevent movement during transport. (i.e., over-pack in secondary container)
 - (6) Have a spill kit readily accessible in the event of a small spill. In the event of a large spill while in transport, notify 911 to request assistance with chemical spill clean up.
- d. Vehicles that transport chemicals shall be inspected by the operator for possible contamination prior to departure and upon return. Vehicles determined to be contaminated must be decontaminated according to the MSDS.

F. SECONDARY CONTAINMENT AND SPILL CONTROL

1. Liquid chemicals must be stored in corrosion-resistant trays or on spill pallets or other secondary containment to contain a break or leak.
2. Concentrated acids and bases should be stored in acid or caustic storage cabinets. If possible, keep corrosives stored in their original (e.g. Styrofoam cubes) shipment containers.
3. In the event of a chemical spill, try to turn off all reaction apparatus, especially heat sources, notify supervision immediately and follow the response steps in your facility's "Hazardous Chemicals Emergency Spill And Leak Control Procedures, Reporting Person's Check List".

G. CABINET AND SHELF STORAGE - GENERAL PRECAUTIONS

1. Cabinets and other storage areas are to be marked with the general class of chemical stored, and any other pertinent warnings.
2. Storage areas should have good general ventilation and be well lighted.
3. On shelves, containers should be staggered for easy access, with labels facing out. Do not alphabetize stored chemicals; separate by compatibility (see next section).
4. Heavy and large containers are to be placed on bottom shelves. Chemicals, especially liquids, should be stored below eye level. Larger containers should be stored on lower shelves. Exposure to heat or direct sunlight must be avoided. Avoid storing chemicals on the floor unless in approved shipping containers. Minimize open shelf or bench top storage, except for those chemicals being

5. Cabinets specifically for corrosives (either acids or bases) must have corrosion-resistant paint. Flammable storage cabinets must be constructed to meet the NFPA 30 - *Flammable and Combustible Liquids Code* - and provide an airtight seal; vent holes must be kept covered and flame-arrestor kept in place. Flammable liquids cabinets must be UL Listed or FM Approved for storing flammable liquids.
6. Oxidizers MUST be stored in separate cabinets from flammables and combustibles. Oxidizers, explosives, and organic peroxides must be separated from combustibles and placed in a metal cabinet, or in an approved dry, cool, and well-ventilated location. Refer to [Chapter 38, "Fire Prevention"](#), of this *Manual* for further requirements.
7. If acids and bases must be stored together in the same cabinet, place each in separate secondary containers (non-reactive trays) on opposite sides of the cabinet to minimize intermingling in case of a spill or drip (in other words, do not store all the acids on one shelf, and all the bases on the shelf below).
8. Initially assign each chemical to broad hazard classes, for example: flammable, corrosive (acids and bases), reactive oxidizer, or reducer, special hazard (air/water reactive, peroxide forming chemical, store at reduced temperature or under an inert atmosphere, highly toxic).
9. Chemicals that possess more than one hazard (i.e., oxidizer and corrosive) are assigned to the class that, in the judgment of the Safety Coordinator and OSHEM, represents the greater hazard for that work area.
10. Post incompatibility lists (Attachment 1 or equivalent, and from your MSDSs) for reference.

H. REFRIGERATORS AND FREEZERS - FLAMMABLE STORAGE

1. All refrigerators or freezers shall be distinctly marked as to whether it is suitable for the storage of flammable liquids.
2. All refrigerators housing flammable liquids shall be of the "flammable safe" or explosion proof variety, and shall be UL Listed or FM Approved for such use. Standard household variety refrigerators shall not be used to store flammable liquids.
3. **NOTE:** Refrigerators, freezers, and cooling equipment located in a work area designated as a Class I location, shall be approved for use in a Class I, Division 1 or 2 location and shall be installed per the NEC.
4. Flammable liquids stored in refrigerated equipment shall be in closed containers.

I. STORAGE OF CHEMICALS BY CLASS

1. Flammables and Combustibles. Flammables are chemicals that have a flash point less than 100°F. Combustible chemicals have flash points that are 100-200°F. If stored or used improperly, flammables and combustibles can be a fire hazard.
 - a. *Examples:* benzene, alcohols, hydrogen sulfide, acetone, ethers, organic acids (i.e., glacial acetic acid)
 - b. In general, handling and storage of flammable liquids shall comply with NFPA 30 – *Flammable and Combustible Liquids Code*, as well as meet the requirements of [Chapter 36, “Fire Protection”](#), and [Chapter 38, “Fire Prevention”](#), of this *Manual*.
 - c. For all areas, chemical container types and maximum capacities shall comply with [Attachment 2](#) of this Chapter.
 - d. The quantity of hazardous chemicals within a laboratory unit or in a laboratory work area, that is stored in the open, shall be limited to the minimum necessary to perform required tasks. However, in no case should they exceed the quantity allowed by the laboratory unit classifications, as indicated in [Attachments 3](#) and [4](#) of this Chapter.
 - e. To the greatest degree possible, the storage of flammable liquids in a work area, outside of an approved flammable liquids cabinet or storage room, should be limited to what is needed for a single day’s use. Otherwise, flammable liquids should be stored within an approved flammable liquids cabinet when not in use.
 - f. Bulk supplies of flammable/combustible liquids (such as pure material [95% EtOH] in drums) shall be stored in an approved flammable liquids storage room. For the purposes of the *Safety Manual*, “bulk supply” shall be defined as more flammable/combustible liquid than can be safely stored in three approved flammable liquid storage cabinets, which are located in a single area (360 gallons, total).
2. Corrosives: Acids. Acids are corrosive and react violently with bases. There are two main groups of acids: organic acids, and inorganic (mineral) acids. Some inorganic (mineral) acids are oxidizers and will react with organics, increase burning rate of combustibles and contribute an oxygen source to a combustion reaction. Therefore, inorganic (mineral) acids should be stored separately from organic acids.
 - a. *Examples of inorganic OXIDIZING acids:* perchloric acid (particularly dangerous at elevated temperature), chromic acid, nitric acid, sulfuric acid (particularly dangerous at elevated temperature).
 - b. *Examples of inorganic MINERAL acids:* hydrochloric acid, hydrofluoric acid, phosphoric acid
 - c. *Examples of organic acids:* acetic acid, formic acid, butyric acid, propionic acid, picric acid, acrylic acid.
 - d. Nitric acid shall be stored separate from other acids.

- e. Segregate acids from bases and active metals such as potassium and magnesium.
 - f. Segregate acids from chemicals that could generate toxic gases upon contact, such as sodium cyanide.
 - g. Segregate acids from solvents such as toluene and xylene.
 - h. Segregate oxidizing inorganic acids from organic acids, flammable and combustible materials. Most mineral acids can be stored together, except perchloric acid (see below).
3. Organic acids (e.g., glacial acetic acid) can be combustible and should be stored separately or with flammables rather than with inorganic acids. Several inorganic acids are oxidizers and therefore, incompatible with organic acids
4. Perchloric acid and picric acid require special handling.
- a. *Picric acid* is reactive with metals or metal salts and is potentially explosive when dry. Contaminated picric acid is particularly dangerous, as picrate metal salts are potentially explosive compounds. Picric acid must be stored wet with at least 10% water. Store picric acid in a cool, dry, non-ventilated area away from incompatibles or ignition sources.
 - b. *Perchloric acid* at elevated temperature is a very strong oxidizer. It can react with metals, wood and other combustibles to form potentially explosive compounds. For information on the handling, storage and use of perchloric acid, contact your Safety Coordinator.
5. Corrosives: Bases. Bases are corrosive and react violently with acids.
- a. *Examples:* ammonium hydroxide, sodium hydroxide, calcium hydroxide, organic amines
 - b. Segregate bases from acids. Bases are also corrosive to skin and tissue. Pay meticulous attention to personal protective equipment when using bases.
6. Reactive: Oxidizers (Attachment 5). Oxidizers react vigorously with reducing materials. The reaction can lead to fires or explosions. Oxidizers will increase the burning rate of combustible materials and contribute oxygen to a combustion reaction.
- a. *Examples:* halogens, ammonium persulfate, hydrogen peroxide, sodium dichromate, potassium permanganate, perchloric acid, at elevated temperature, ammonium nitrate (and other nitrate salts)
 - b. Keep oxidizers away from flammables, combustibles (such as paper, wood) and other reducing agents.
7. Reactive: Reducers. Reducing materials react vigorously with oxidizers. The reaction can lead to fires or explosions.

- a. *Examples:* ammonia, carbon, air-reactive metals, metal hydrides, phosphorus, silicon, sulfur
 - b. Store reducing materials away from oxidizers.
8. Water-reactive Chemicals. Water reactive materials react with water, water solutions, moisture, or humidity in the air to produce heat and/or flammable gases, which can ignite.
 - a. *Examples:* sodium (elemental), potassium (elemental), lithium, calcium carbide, phosphorous pentachloride.
 - b. Store water reactives away from any sources of water or moisture. Review manufacturer's recommendations for special storage conditions, such as under an inert atmosphere or, as in the case of elemental sodium, under mineral oil.
9. Peroxide Forming Chemicals (Attachment 6). Potentially explosive peroxides are formed by a free-radical reaction of hydrocarbons with molecular oxygen. Distillation, evaporation or other concentration of the peroxide can cause an explosion in contaminated hydrocarbons.
 - a. *Examples:* diethyl ether, tetrahydrofuran, acetaldehyde, isopropyl ether
 - b. Store peroxide-forming chemicals away from light and heat. Carefully label all containers with the date received and the date opened. Monitor container dates and avoid keeping peroxide-forming chemicals on hand for more than a year after receipt and 6 months after opening.

J. HIGHLY HAZARDOUS CHEMICALS

1. Special attention is to be made for safe work practices involving "highly hazardous" chemicals, defined as chemical carcinogens, reproductive toxins, acutely toxic substances, and highly reactive materials ([Attachment 7](#), plus MSDS information).
2. Designate a Restricted Work Area. Conduct all transfers and work with these substances in a "controlled area" (i.e., a restricted access hood, glove box, or portion of a lab designated for use of highly toxic substances) for which all personnel with access are aware of the substances being used and the necessary precautions that must be taken. Only trained and authorized personnel are to work in or have access to controlled areas.
3. Signs and labels. Assure that the controlled area is conspicuously marked with restricted access and warning signs, such as, "WARNING: Highly-Toxic Substance in Use: Authorized Personnel Only" or "WARNING: Cancer-Suspect Agent: Authorized Personnel Only." All containers of these substances must be appropriately labeled with identity and warning such as, "Warning: High Chronic Toxicity or Cancer Suspect Agent".

4. Storage. Store containers of these chemicals in a ventilated, limited access area in appropriately labeled, unbreakable, chemically resistant, secondary containers.
5. Establish Decontamination Procedures. The need for routine decontamination of designated work area, equipment, or personnel depends on the task or work area circumstances. The Safety Coordinator and OSHEM are to be consulted for specific appropriate decontamination procedures.
6. Medical surveillance. When using a highly-toxic substance on a regular basis, staff should consult the Occupational Health Services Division (OSHEM) concerning medical surveillance or other health concerns they may have.
7. Cleanup and Waste Disposal. Use chemical decontamination whenever possible. Use a vacuum cleaner equipped with a High Efficiency Particulate Air (HEPA) filter, instead of dry sweeping when the toxic substance is a dry powder. A wet mop may also be used when the chemical is not water reactive or otherwise incompatible with water. Ensure that all vacuum filters, bag debris, mop heads or cleaning rags, as well as waste chemicals are transferred from the designated control according to the SI Hazardous Waste Disposal Program. Ensure that contingency plans, equipment, and materials are available to minimize exposures to personnel and property in the event of an accident. Do not ask/expect custodial staff to clean hazardous materials spills, unless they are already members of the facility's trained response team.

K. TRAINING. Employers must provide training on how to use hazardous substances safely, in accordance with [Chapter 25, "Chemical Hazard Communication"](#), of this *Manual*, and any specific training required of specific Operational Topic Chapters listed in the Introduction to the Chapter.

L. REFERENCES

1. NFPA 30 - Flammable and Combustible Liquids Code, 2008 edition.
2. NFPA 45 – Fire Protection for Laboratories Using Chemicals, 2004 edition.

CHEMICAL INCOMPATIBILITIES, SELECTED LISTING

Sources: *University of New Hampshire-Biological and Chemical Safety Plan; Safety in Academic Chemistry Laboratories*, published by The American Chemical Society; *Prudent Practices in the Laboratory*, 1995; National Academic Press

The following list is to be used only as a guide. Specific incompatibilities are listed in appropriate MSDSs.

CHEMICAL	INCOMPATIBLE WITH:
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetone	Concentrated nitric and sulfuric acid mixtures
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali and alkaline earth metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, magnesium, calcium, lithium, halogens, sodium, potassium
Aluminum (powdered)	Chlorinated hydrocarbons, halogens, carbon dioxide, organic acids
Ammonia (anhydrous)	Mercury (e.g., in manometers), chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium nitrate	Acids, powdered metals, flammable liquids, chlorates, nitrites, sulfur, finely divided organic combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenic materials	Any reducing agent
Azides	Acids
Bromine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals, turpentine
Calcium carbide	Water, alcohol
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents
Chlorates	Ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials

Chromic acid & chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, alcohol, turpentine, flammable liquids in general.
Chlorine	<i>See bromine</i>
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cyanides	Acids
Fluorine	Isolate from all other chemicals
Hydrocarbons (such as butane, propane, benzene)	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkali
Hydrofluoric acid (anhydrous) & hydrogen fluoride	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidizing gases
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous) hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Mercuric oxide	Sulfur
Nitrates	Acids (especially sulfuric acid)
Nitric acid (concentrated)	Acetic acid, alcohols, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids and gases, copper, brass, any heavy metals
Nitrites	Acids

Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury
Oxygen	Oils, grease, hydrogen; flammable liquids, solids and gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils
Peroxides, organic	Acids (organic or mineral), avoid friction or shock, store cold
Phosphorous (white)	Air, oxygen, alkalis, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids
Potassium perchlorate	Sulfuric and other acids, <i>see also chlorates</i>
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrate	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethylacetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (similar compounds of light metals, such as sodium, lithium)
Tellurides	Reducing agents
Zinc powder	Sulfur

FLAMMABLE/COMBUSTIBLE LIQUIDS: MAXIMUM ALLOWABLE CONTAINER CAPACITY

Maximum Allowable Container Capacity					
Container Type	Flammable Liquids			Combustible Liquids	
	IA	IB	IC	II	IIIA
Glass	500mL (1 pt) ¹	1L (1 qt) ¹	4L(1 gal)	4L (1 gal)	20L (5gal)
Metal (other than drums) or approved plastic	4L (1 gal)	20L (5 gal)	20L (5 gal)	20L (5 gal)	20L (5 gal)
Safety cans	10L (2.6 gal)	20L (5 gal)	20L (5 gal)	20L (5 gal)	20L (5 gal)
Metal container (DOT spec.)	4L (1 gal)	20L (5 gal)	20L (5 gal)	227L (60 gal)	227L (60 gal)
Polyethylene (DOT Spec. 34, UN1H1, or as authorized by DOT exemption)	4L (1 gal)	20L (5 gal)	20L (5 gal)	227 L (60 gal)	227L (60 gal)
Container-type pressurized liquid dispensing container	20L (5 gal)	227L (60 gal)	227L (60 gal)	227L (60 gal)	227L (60 gal)

* This table is based on Table 10.1.4 of NFPA 45– Fire Protection for Laboratories Using Chemicals

MAXIMUM QUANTITIES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS AND LIQUEFIED FLAMMABLE GASES IN SPRINKLERED LABORATORY UNITS OUTSIDE OF INSIDE LIQUID STORAGE AREAS

Maximum Quantities of Flammable and Combustible Liquids and Liquefied Flammable Gases in Sprinklered Laboratory Units Outside of Inside Liquid Storage Rooms									
		<i>Excluding Quantities in Storage Cabinets* or Safety Cans</i>				<i>Including Quantities in Storage Cabinets** or Safety Cans</i>			
		<i>Max. Quantity per 100 ft.² of Laboratory Unit</i>		<i>Max. Quantity per Laboratory Unit</i>		<i>Max. Quantity per 100ft.² of Laboratory Unit</i>		<i>Max. Quantity per Laboratory Unit</i>	
<i>Laboratory Unit Fire Hazard Class</i>	<i>Flammable and Combustible Liquid Class</i>	L	gal	L	gal	L	gal	L	gal
A High fire hazard	I*	38	10	2270	600	76	20	4540	1200
	I, II, and IIIA	76	20	3028	800	150	40	6060	1600
B Moderate fire hazard	I*	20	5	1136	300	38	10	2270	600
	I, II, and IIIA	38	10	1515	400	76	20	3028	800
C Low fire hazard	I*	7.5	2	570	150	15	4	1136	300
	I, II, and IIIA	15	4	757	200	30	8	1515	400
D Minimal fire hazard	I*	4	1	284	75	7.5	2	570	150
	I, II, and IIIA	4	1	284	75	7.5	2	570	150

* This category includes Class I flammable liquids and liquefied flammable gases.

** Quantities of liquefied flammable gases shall be treated as if they were Class I flammable liquids; that is, (1.1 gal) of liquefied flammable gas is to be considered equivalent to (1.1 gal) of Class I flammable liquid.

Note: This table is based on Table 10.1.1 of NFPA 45 – Fire Protection for Laboratories Using Chemicals

MAXIMUM QUANTITIES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS AND LIQUEFIED FLAMMABLE GASES IN NON-SPRINKLERED LABORATORY UNITS OUTSIDE OF INSIDE LIQUID STORAGE AREAS

Maximum Quantities of Flammable and Combustible Liquids and Liquefied Flammable Gases in Non-Sprinklered Laboratory Units Outside of Inside Liquid Storage Rooms									
		<i>Excluding</i> Quantities in Storage Cabinets* or Safety Cans				<i>Including</i> Quantities in Storage Cabinets** or Safety Cans			
		<i>Max. Quantity per 100 ft.² of Laboratory Unit</i>		<i>Max. Quantity per Laboratory Unit</i>		<i>Max. Quantity per 100ft.² of Laboratory Unit</i>		<i>Max. Quantity per Laboratory Unit</i>	
<i>Laboratory Unit Fire Hazard Class</i>	<i>Flammable and Combustible Liquid Class</i>	L	gal	L	gal	L	gal	L	gal
A High fire hazard	I*	NP	NP	NP	NP	NP	NP	NP	NP
	I, II, and IIIA	NP	NP	NP	NP	NP	NP	NP	NP
B Moderate fire hazard	I*	NP	NP	NP	NP	NP	NP	NP	NP
	I, II, and IIIA	NP	NP	NP	NP	NP	NP	NP	NP
C Low fire hazard	I*	7.5	2	284	75	15	4	570	150
	I, II, and IIIA	15	4	380	100	30	8	760	200
D Minimal fire hazard	I*	4	1.1	140	37	7.5	2	284	75
	I, II, and IIIA	4	1.1	140	37	7.5	2	284	75

NP – Not Permitted

* This category includes Class I flammable liquids and liquefied flammable gases.

** Quantities of liquefied flammable gases shall be treated as if they were Class I flammable liquids; that is, (1.1 gal) of liquefied flammable gas is to be considered equivalent to (1.1 gal) of Class I flammable liquid.

Note: This table is based on Table 10.1.5 of NFPA 45 – Fire Protection for Laboratories Using Chemicals

HIGH ENERGY OXIDIZERS

(Source: CRC Handbook of Laboratory Safety, 5th Ed)

Ammonium perchlorate (NH_4ClO_4)

Ammonium permanganate (NH_4MnO_4)

Barium peroxide (BaO_2)

Bromine (Br_2)

Calcium chlorate ($\text{Ca}[\text{ClO}_3]_2 \cdot 2\text{H}_2\text{O}$)

Calcium hypochlorite ($\text{Ca}[\text{ClO}]_2$)

Chlorine trifluoride (ClF_3)

Chromium anhydride or chromic acid (CrO_3)

Dibenzoyl peroxide ($[\text{C}_6\text{H}_5\text{CO}]_2\text{O}_2$)

Fluorine (F_2)

Hydrogen peroxide (H_2O_2)

Magnesium perchlorate ($\text{Mg}[\text{ClO}_4]_2$)

Nitric acid (HNO_3)

Nitrogen peroxide (in equilibrium with nitrogen dioxide) N_2O_4 ; NO_2

Nitrogen trioxide (N_2O_3)

Perchloric acid (HClO_4)

Potassium bromate (KBrO_3)

Potassium chlorate (KClO_3)

Potassium perchlorate (KClO_4)

Potassium peroxide (K_2O_2)

Propyl nitrate (normal) ($\text{CH}_3[\text{CH}_2]_2\text{NO}_3$)

Sodium chlorate (NaClO_3)

Sodium chlorite (NaClO_2)

Sodium perchlorate (NaClO_4)

Sodium peroxide (Na_2O_2)

PEROXIDE-FORMING MATERIALS

Types of Compounds Known to Auto-Oxidize to Form Peroxides

(Source: Prudent Practices in the Laboratory, 1995)

- Aldehydes
- Ethers, especially cyclic ethers and those containing primary and secondary alkyl groups
- Compounds containing benzylic hydrogens
- Compounds containing allylic hydrogens including most alkenes; vinyl and vinylidenes
- Compounds containing a tertiary C-H group

Classes of Chemicals that can Form Peroxides Upon Aging

(Source: Prudent Practices in the Laboratory, 1995)

<i>Unsaturated materials may polymerize violently due to peroxide initiation:</i>		
Acrylic acid	Methyl methacrylate	Vinyl chloride
Acrylonitrile	Styrene	Vinyl pyridine
Butadiene	Tetrafluoroethylene	Vinylidene chloride
Chlorobutadiene (chloroprene)	Vinyl acetate	
Chlorotrifluoroethylene	Vinyl acetylene	
<i>Peroxide hazards upon concentration (distillation/evaporation):</i>		
Acetal	Dicyclopentadiene	Methyl acetylene
Cumene	Diethylene glycol dimethyl ether	Methyl cyclopentane
Cyclohexene	Diethyl ether	Methyl- <i>i</i> -butyl ketone
Cyclooctene	Dioxane	Tetrahydrofuran
Cyclopentene	Ethylene glycol dimethyl ether	Tetrahydronaphthalene
Diacetylene	Furan	Vinyl ethers
<i>Peroxides derived from the following may explode without concentration:</i>		
Organic: Divinyl ether Divinyl acetylene Isopropyl ether Vinylidene chloride	Inorganic: Potassium metal Potassium amide Sodium amide	

CARCINOGENS

Source: *Report on Carcinogens, Eleventh Edition*; U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, January 2005

<http://ntp.niehs.nih.gov/index.cfm?objectid=72016262-BDB7-CEBA-FA60E922B18C2540>

ACUTE TOXICANTS

This discussion is adapted from *Prudent Practices in the Laboratory*, 1995, National Academy Press.

Acute toxicity is the ability of a chemical to cause a harmful effect after a single exposure. Among the most useful parameters for assessing the risk of acute toxicity of a chemical are its LD₅₀ and LC₅₀ values, selected with due regard for the possible routes of exposure. These values can be found in the MSDS for the chemical, or in any number of literature or web-based references noted in Appendices B and C of this *Manual*. It is useful to classify and compare your chemicals and their values with the following table taken from *Prudent Practices*, page 42.

Hazard Level	Toxicity Rating	Oral LD50 (rats per kg)	Skin Contact LD50 (rabbits, per kg)	Inhalation LC50 (Rats, ppm for 1 hr)	Inhalation LC50 (Rats, mg/m ³ for 1 hr)
High	Highly Toxic	<50 mg	<200 mg	<200	<2,000
Moderate	Moderately toxic	50 to 500 mg	200mg to 1 g	200 to 2,000	2,000 to 20,000
Low	Slightly toxic	500 mg to 5 g	1 to 5 g	2,000 to 20,000	20,000 to 200,000

Substances with values qualifying for “High” hazard levels meet the definition of highly hazardous (Section J.1. in this Chapter) for the purpose of special controls.