VII. Chemicals: Managing, Handling and Disposing

Safety in Ordering, Storing, Using and Disposing of Chemicals

MAINTAINING CHEMICAL SAFETY REQUIRES . . .

- **careful selection of all reagent chemicals.**
- **accurate assessment of relative hazards of chemicals.**
- **proper labeling and storage of all chemicals.**
- **safe use of all materials.**
- **proper disposal of all materials.**

Maintaining chemical safety requires care in ordering, storing, using, and disposing of chemicals. Chemical safety is the responsibility of everyone who uses the classroom laboratory, but safe management of chemicals begins with the teacher who orders and uses these products.

Safe management of chemicals in the classroom requires that the teacher have adequate knowledge of the chemicals to be used and their interactions. Information about these chemicals is available on the Materials Safety Data Sheets (MSDSs) for each chemical, in chemical catalogues, and on container labels. An Internet search under the keyword "MSDS" will yield information on websites that supply information on chemicals.
▸*See* Appendix C, MSDS: Explanation and Samples.

Before making a request to use a reagent chemical not on the school system's approved list, the teacher should read and research the appropriate MSDS to determine whether the chemical can be safely used with students. The teacher also should consider --

- the relative hazard level of the chemical.
- the educational value of using the chemical.
- the teacher's experience or lack of experience in using the substance.
- the degree to which the laboratory is equipped for the safe use of the chemical.
▸*See* Chapter III.E, Ventilation.

A. Managing Reagent Chemicals

1. **Selecting Reagent Chemicals**

   Each school system should develop a list of reagents acceptable for use in the various science courses. A teacher who wishes to use a substance not on the appropriate list must seek the permission of the science supervisor by submitting a written request. The request should include the following:

   a. A copy of the lesson plan for the proposed demonstration or laboratory exercise.

   b. Information supporting the following assertions:

      - Use of the substance is pedagogically sound.
      - The demonstration or laboratory exercise using the substance is an effective way to illustrate an important property, process or concept.

- No satisfactory substitute for the substance is readily available.
- Adequate safeguards are in place to ensure proper use of the substance.
- Students will be instructed in the proper handling of the substance (as indicated in the lesson plan).

c. Information on the following to enable the supervisor to make an informed decision:

- the extent of exposure of students and the teacher to the chemical (including estimate of time to the nearest minute).
- the age or maturity level of the students who will be exposed.
- the recommended maximum levels of exposure set by regulatory and/or professional organizations.

d. In considering a substance for use in the laboratory, teachers are advised to check hazardous materials lists available in print and on the Internet. Resources available include the following:

- The National Toxicological Program for lists of carcinogenic and reproductive toxins (teratogens and mutagens)
- The National Research Council's *Prudent Practices in the Laboratory* (1995), Chapter 3, for lists of carcinogens, mutagens, teratogens, and highly flammable materials
- The Oak Ridge Toxicology Information Resources Center's *Catalog of Teratogenic Agents*

Appearance of a substance on one of these lists does not preclude its appropriate use in the school laboratory. The dose makes the difference. Even common substances such as water and salt can be toxic in excessive quantities. Many substances that are toxic at some levels can safely be used at lower levels.

Materials Safety Data Sheets (MSDSs), which provide information on toxicity levels, may be found on the Internet.

▸*See* Appendix H, Resources.

2. **Ordering Reagent Chemicals**

a. Before ordering reagent chemicals, the teacher should–

- make sure the chemical is on the school system's list of approved chemicals.
- be capable of assessing the hazards of chemicals.
- be sufficiently knowledgeable to recognize requests from other teachers for nonessential chemicals.

- have a current inventory of existing chemicals.

  ▸*See* Chapter VII.A.3, Chemical Inventory.

b. Reagent chemicals should be ordered in quantities consistent with the rate of use.

c. Reagent chemicals should be ordered in polyethylene bottles or plastic-coated bottles, if available, to minimize breakage, corrosion, and rust.

d. For each reagent chemical used, ask the following questions:

- Can proper storage be provided for the chemical?
- Are the facilities appropriate for the use of the chemical?
- Will the chemical or its end products require disposal as hazardous waste?
- Is appropriate personal protective equipment available for safe use of the chemical or its end product?
- Have persons who will handle and use the chemical been trained in handling reagent chemicals? Are they aware of the hazards?

3. Chemical Inventory


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Inventories of reagents are essential in the control of chemical hazards. They enable members of the science department to determine the existence of a specific reagent chemical, its location, and its approximate shelf age. A reagent chemical inventory should be conducted at least once a year. The chemical inventory record should–

- contain the date the inventory was conducted.
- identify chemical reagents by name and formula.
- specify the amount of each reagent present.
- indicate the storage location of each reagent.
- indicate the hazard of each reagent, using information from the Material Data Safety Sheet (MSDS) for each substance and the appropriate National Fire Protection Association hazard code.

  ▸*See* Appendix E, NFPA Identification Codes, and Appendix C, Materials Data Safety Sheets (MSDS): Explanation and Samples.
- indicate the arrival date and quantity of all reagents received.


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4. Chemical Storage

a. General Guidelines

- Secure storage areas against unauthorized removal of chemicals by students or others.
- Protect the school environment by restricting emissions from stored reagent chemicals. Vents should be ducted to the outside.

- Where possible, storage areas should have two separate exits.
- Maintain clear access to and from the storage areas.
- Do not store chemicals in aisles or stairwells, on desks or laboratory benches, on floors or in hallways, or in fume hoods.
- Use NFPA- or OSHA-approved storage cabinets for flammable chemicals.
- Use an appropriate "Acid Cabinet" for any acid solutions of 6 M concentration or higher. Nitric acid needs to be isolated.
- Use refrigerators of explosion-proof or explosion-safe design only. Do not use standard refrigerators to store flammable chemicals. Place *NO FOOD* labels on refrigerators used to store chemicals.
- Label storage areas with a general hazard symbol to identify hazardous chemicals and indicate correct fire fighting procedures.
  ▸*See* Appendix E, NFPA Hazard Codes.
- File a Material Safety Data Sheet (MSDS) for every chemical stored in the laboratory.
- Store all reagent chemicals in compatible family groups. Do not alphabetize.
  ▸*See* Appendix F, Storage of Chemicals.
- Store all chemicals at eye level and below. The preferred shelving material is wood treated with polyurethane or a similar impervious material. All shelving should have a two-inch lip. If you use shelving with metal brackets, inspect the clips and brackets annually for corrosion and replace as needed.
- Store chemical reagents prepared in the laboratory in plastic bottles (if possible and appropriate to the chemical) to minimize the risk of breakage.
- Date containers upon receipt and again when opened.
- Attach chemical labels with all necessary information to all containers.
  ▸*See* Chapter VII.A.5, Labeling of Stored Reagent Chemicals.
- When opening newly received reagent chemicals, immediately read the warning labels to be aware of any special storage precautions such as refrigeration or inert atmosphere storage.
- Test peroxide-forming substances periodically for peroxide levels; dispose of these substances after three months unless the MSDS for the substance indicates a longer shelf life.

  ▸*See* Appendix G, Hazards of Peroxide-Forming Substances, and Appendix C, Materials Data Safety Sheets (MSDS): Explanation and Samples.

- Check chemical containers periodically for rust, corrosion, and leakage.
- Store bottles of especially hazardous and moisture-absorbing chemicals in chemical-safe bags.
- Maintain a complete inventory in the room where the chemicals are stored, and make a copy available to fire fighters.
- Keep storage areas clean and orderly at all times.
- Have spill cleanup supplies (absorbents, neutralizers) in any room where chemicals are stored or used.

b. **Storage of Flammable and Combustible Liquids**

(1) Definitions

Flash point is defined as the minimum temperature of a liquid at which it gives off sufficient vapor to form an ignitable mixture with air.

Flammable liquid is defined as any liquid that has a flash point below 100 °F (37.8 °C).

Combustible liquid is defined as any liquid that has a flash point at or above 100 °F (37.8 °C).

(2) Guidelines

- Limit the amount of flammable and combustible materials stored to that required for one year of laboratory work.
- Use only NFPA- or OSHA-approved metal flammables cabinets to store flammable and combustible liquids. Label the cabinets *FLAMMABLE - KEEP AWAY FROM FIRE*.


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- When possible, store flammable and combustible liquids in their original containers or safety cans. A safety can is an approved container of not more than 5 gallons (18.9 L) capacity. The container should have a spring-closed spout cover and an integral flame-arrester and be designed to relieve internal pressure safely when exposed to fire.


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c. **Storage of Compressed Gases**

- Use small lecture-bottle-type gas cylinders only. Store all gas cylinders in an upright position.
- Store gas cylinders in a cool dry place away from corrosive chemicals or fumes.
- Store gas cylinders away from highly flammable substances.
- When cylinders are no longer in use, shut the valves, relieve the pressure in the gas regulators, removed the regulators, and cap the cylinders.

- Label empty gas cylinders *EMPTY* or *MT*.
- Store empty gas cylinders separately from full gas cylinders.
- Store flammable or toxic gases at or above ground level–not in basements.
- Use cylinders of toxic, flammable, or reactive gases in fume hoods only.
- When moving cylinders, be sure the valve cap is securely in place to protect the valve stem and valve. Do not use the valve cap as a lifting lug.
- If large gas cylinders are used, they should be chained. A hand truck should be available for transporting them to and from the storage area.

5. **Labeling of Stored Reagent Chemicals**

Proper labeling is fundamental to a safe and effective laboratory operation. Reagents created in the laboratory also require labeling.

a. **Purchased Reagent Chemicals**

All purchased reagent chemicals should be labeled with–

- chemical name.
- date received.
- date of initial opening.
- shelf-life.
- hazard warnings.
  ▸*See* Appendix E, NFPA Identification Codes.
- storage classification location.
- name and address of manufacturer.

b. **Solutions**.

All reagents created in the laboratory should be labeled with–

- chemical name and formula.
- concentration.
- date prepared.
- name of person who prepared the reagent.
- storage classification.
- hazard warning label (available from a safety supplier).
- reference to original source of chemical (e.g., manufacturer, which jar, etc.).

B. Handling Reagent Chemicals

1. Dispensing Reagent Chemicals

The MSDS for an individual substance should always be consulted before a chemical is used for any reason. It is the best source of information about possible hazards, spill procedures, handling procedures and first aid for any substance.

Teachers are responsible for instructing their students about safe methods for working with chemicals.

a. Safety Guidelines for Dispensing Reagent Chemicals

- Use the smallest amount of the chemical possible in any experiment. Microscale experiments should be considered.
- Consider distributing the amount of chemical for an experiment into vials for each student. This minimizes waste and can save time during the class period.
- Use proper containers for dispensing solids and liquids. Solids should be contained in wide-mouthed bottles and liquids in containers that have drip-proof lips.
- Label all containers properly.
- Never return dispensed chemicals to stock bottle, as it inevitably results in contamination despite your best precautions.

b. Dispensing Flammable Liquids

When a liquid flows from one container to another, static electricity can build up in one of the containers. If this charge becomes large enough, a spark will be produced between the containers, and a flammable liquid may be ignited. This is particularly a danger when the liquid is stored in a large container and distributed to smaller containers.

Such containers should be *bonded* and *grounded:*

- *Bonding* refers to providing an electrical connection between the two containers. Commonly this is accomplished by attaching a wire, fastening one end each to the two containers.
- *Grounding* refers to connecting one of the containers (usually the stationary one) to a grounding source such as a metallic water pipe.

2. Common Hazards

Four categories of hazards commonly found in school laboratories are: corrosives, flammables, oxidizers/reactives, and toxins. In this section, mercury is discussed separately as a special hazard.

a. **Corrosives**

Corrosives are materials that can injure body tissue or cause corrosion of metal by direct chemical action. Major classes of corrosive substances are:

- strong acids (e.g., sulfuric, nitric, hydrochloric and hydrofluoric acids)
- strong bases (e.g., sodium hydroxide and potassium hydroxide)
- dehydrating agents (e.g., sulfuric acid, sodium hydroxide, phosphorus pentoxide, and calcium oxide)
- oxidizing agents (e.g., hydrogen peroxide, chlorine, and bromine)

b. **Flammables**

Flammable substances have the potential to catch fire readily and burn in air. A flammable liquid itself does not catch fire; it is the vapors produced by the liquid that burn. Important properties of flammable liquids:

- Flash point is the minimum temperature of a liquid at which sufficient vapor is given off to form an ignitable mixture with air.
- Ignition temperature is the minimum temperature required to initiate self-sustained combustion independent of a heat source.

▸*See* Chapter VII.A.4.b, Storage of Flammable and Combustible Liquids.

c. **Oxidizers / Reactives**

Oxidizers / reactives include chemicals that can explode, violently polymerize, form explosive peroxides, or react violently with water or atmospheric oxygen.

(1) *Oxidizers*. An oxidizing agent is any material that initiates or promotes combustion in other materials, either by causing fire itself or by releasing oxygen or other combustible gases.

(2) *Reactives*: Reactives include materials that are pyrophoric ("flammable solids"), are water reactive, form explosive peroxides, or may undergo such reactions as violent polymerization.

d. **Toxins**

A toxic substance is one that, even in small amounts, can injure living tissue.

(1) Methods of Toxins Entering the Body:

- *Ingestion* - Absorption through the digestive tract. This process can occur through eating with contaminated hands or in contaminated areas.

- *Absorption* - Absorption through the skin often causes dermatitis. Some toxins that are absorbed through the skin or eyes can damage the liver, kidney, or other organs.
- *Inhalation* - Absorption through the respiratory tract (lungs) through breathing. This process is the most important route in terms of severity.
- *Injection* - Percutaneous injection of a toxic substance through the skin. This process can occur in the handling of sharp-edged pieces of broken glass apparatus and through misuse of sharp materials such as hypodermic needles.

(2) Types of Toxins


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OSHA defines a hazardous chemical as any chemical that is a physical or a health hazard (CFR 1910.1200). Many chemicals can cause toxic effects in the body. Below are some classes of toxic chemicals. Information about these chemicals is available on the MSDS for each chemical, in chemical catalogues, on container labels, and on several Internet sources.

- *Irritants* are noncorrosive chemicals that cause reversible inflammatory effects (swelling and redness) on living tissue by chemical action at the site of contact. Because a wide variety of organic and inorganic chemicals are irritants, skin and eye contact with all chemicals in the laboratory should be avoided.
- *Corrosive substances* are solids, liquids, and gases that cause destruction of living tissue by chemical action at the site of contact.
- *Allergens* are substances which cause an adverse reaction by the immune system. As these reactions result from previous sensitization from the substance or similar substance, chemical allergens will be different for each person.
- *Asphyxiants* are substances that interfere with the transport of an adequate supply of oxygen to the vital organs of the body. They can do this by either displacing oxygen from the air or by combining with hemoglobin and thus reducing the blood's ability to transport oxygen.
- *Carcinogens* are cancer-causing substances listed in the *Annual Report on Carcinogens*. Many substances known or suspected to be carcinogenic are still found to be in high school laboratories. There is little reason for most of them to be there; they should be disposed of as quickly as possible.

- *Reproductive & developmental toxins* (teratogens and mutagens) either have an adverse effect on the various aspects of reproduction (fertility, gestation, lactation and general reproductive performance) or act during pregnancy to cause adverse effects on the embryo or fetus.
- *Neurotoxins* induce an adverse effect on the structure or function of the central and/or peripheral nervous system. These effects can be permanent or reversible.
- *Toxins affecting other organs* can also be a hazard. Most of the chlorinated hydrocarbons and aromatic compounds, some metals, carbon monoxide, cyanides, and others can produce one or more effects on target organs in the body.

e. **Mercury**

Mercury and its compounds, both organic and inorganic, are health hazards. Metallic mercury has a measurable vapor pressure, and the production of vapor is accentuated by heating the mercury or subdividing as occurs in a spill. Laboratory sources of mercury include, among others, thermometers, manometers (barometers), and batteries. Not only is the vapor harmful, but the metal itself is absorbable through the intact skin.

(1) Mercury and its compounds should never be found in the elementary or middle school.

(2) In high schools, mercury should be used only under special circumstances. Mercury is acceptable in high school only if all four of these criteria are met:

- No substitute is available that will provide the degree of accuracy required for the operation.
- The teacher has obtained prior approval from the science supervisor.
- All persons in the laboratory working with mercury or an instrument containing mercury wear chemical splash safety goggles, full face shields, aprons, and adequate clothing to prevent skin contact.
- Access to mercury or any instrument containing the element is restricted by keeping source and instrument under lock and key except when in use.

3. **Spill Cleanup**

a. **General Notes on Chemical Spills**

- Spills should be contained, the area cleared of students, and the spill cleaned up immediately.
- Waste from spill cleanup should be disposed of appropriately.

▸*See* Chapter VII.C, Chemical Waste Strategies.

- After floor spill has been thoroughly cleaned up in the appropriate manner, the area should be mopped dry to minimize the risk of slipping and falling.

b. **Spills that Constitute Fire Hazard**

- Extinguish all flames immediately.
- Shut down all experiments.
- Vacate the room until the situation has been corrected.

c. **Other Spills**

(1) Use an absorbent material to neutralize the liquids. Materials include:

- for acids, powdered sodium bicarbonate
- for bromine, sodium thiosulfate solution (5-10%) or limewater
- for organic acids, halides, nonmetallic compounds, or inorganic acids, use slaked lime and soda ash
- or general spills, use commercial absorbents or spill kits, small particles of clay absorbents (kitty litter), or vermiculite

(2) Wear rubber gloves and use a dustpan and brush. Clean the area thoroughly with soap and water, then mop dry.

(3) Aromatic amine, carbon disulfide, ether, nitrile, nitro compound, and organic halide spills should be absorbed with cloths, paper towels, or vermiculite and disposed of in suitably closed containers.

4. **Mercury Spills**

Whenever possible, mercury should not be used in school laboratories. If and when it is used, however, there is a chance of a spill occurring.

Each laboratory should therefore be equipped with a specialized, commercially available, mercury-spill kit. Follow the directions found in your kit for cleaning up a mercury spill.

C. Chemical Waste Strategies

All laboratory work with chemicals eventually produces chemical waste. Everyone associated with the science laboratory shares the legal and moral responsibility to minimize the amount of waste produced and to dispose of chemical waste in a way that has the least impact on the environment. Depending on what is contained in the waste, some waste must be professionally incinerated or deposited in designated landfills, while other waste can be neutralized or discharged in normal streams.

1. **Minimizing Waste**

a. **Alternative Substances**

Whenever possible, use less toxic substances in place of the more toxic chemicals to minimize the hazards and disposal costs associated with using certain chemicals. The table below contains a list of suggested substitutions for some toxic chemicals.

Toxic Chemical	Substitute
Chloroform	Hexanes
Carbon tetrachloride	Hexanes
1,4-Dioxane	Tetrahydrofuran
Benzene	Cyclohexane or Toluene
Xylene	Toluene
2-Butanol	1-Butanol
Lead chromate	Copper carbonate
p-Dichlorobenzene	Naphthalene, Lauric acid, Cetyl alcohol, 1-Octadecanol, Palmitic acid, or Stearic acid
Potassium	Calcium
Dichromate/Sulfuric acid mixture	Ordinary detergents
Trisodium phosphate	Ordinary detergents
Alcoholic potassium hydroxide	Ordinary detergents

b. **Microscale Laboratories**

Microscale experiments reduce the amount of material required, therefore reducing the hazards encountered and disposal costs. Many laboratory manuals on the market describe microscale experiments. These should be considered whenever possible to replace "classic" laboratory experiments.

c. **Classroom Demonstrations**

Another way to reduce the hazards for students, and reduce the amount of waste generated, is for the teacher to perform classroom demonstrations for the more hazardous experiments rather than have each student carry out the experiment.

d. **Coordinate Laboratory Work**

When planning laboratory experiments, try to coordinate with co-workers who may be doing the same or similar experiments so that reagents are made up at one time in the building, thus minimizing the amount of "left-over" reagent at the end of the experiment.

2. **Waste Storage Prior to Disposal**

a. All waste should be stored in properly labeled containers. The label should contain the date, type of waste, and any other pertinent information required by the disposal company.

b. Waste should be segregated to avoid unwanted reactions and to allow for cost-effective disposal.

c. Waste should be stored in closed containers except when additional waste is being added.

d. Each school science department should maintain a central, secure waste storage area.

3**. Disposing of Waste**

Teachers should be aware of the appropriate method of disposal for any chemical used in the school laboratory. When in doubt, refer to the MSDS, a disposal manual, or the source of the chemical.

a. **Classification of Hazardous Waste**

The Environmental Protection Agency classifies wastes as:

- *Ignitable:* has a flash point below 140°C, is an oxidizer, or is an ignitable compressed gas.
- *Corrosive:* has a pH equal to or below 2.0 or a pH equal to or greater than 12.5.
- *Reactive:* is reactive with air or water, is explosive, or is cyanide or sulfide.
- *Toxic:* has certain levels of certain metals, solvents, or pesticides greater than prescribed limits.
- Others: any chemical found in the lists in 40 CFR 261 subpart D.

b. **Classroom Management**

- Make disposal options a part of all laboratory instructions for students. For each chemical waste produced, instruct students as to the appropriate disposal, including disposing of the substance in a disposal container or down the drain.

▸*See* Chapter VII.C.3.c, Drain Disposal.

- Place all laboratory waste in a properly labeled container. The label should contain the date and type of waste.
- Immediately following the laboratory activity, place the waste containers in a secure location until the containers can be removed to the central storage area.
- Some chemical wastes may be recycled. Teachers should seek guidance on recycling from local safety officers or other knowledgeable administrative staff.

c. **Drain Disposal**

- Before considering drain disposal, be certain that the sewer flows to a wastewater treatment plant and not to a stream or other natural water course. *Check with the local waste water treatment plant authority to determine what substances are acceptable for drain disposal.*
- Any substance from a laboratory should be flushed with *at least* 100 times its own volume of tap water.
- Acids and bases should be at least above pH 3 and below pH 8 before being placed in a sanitary drain.
- If both ions of a compound are on the following lists, that compound may be placed in a sanitary drain:

Positive Ions	Negative Ions
aluminum	borate
ammonium	bromide
bismuth	carbonate
calcium	chloride
copper	cyanate
hydrogen	hydrogen sulfide

Table continued on next page

Positive Ions	Negative Ions
iron	hydroxide
lithium	iodide
magnesium	nitrate
potassium	phosphate
sodium	sulfate
strontium	sulfite
tin	tetraborate
titanium	thiocyanate
zinc	
zirconium	

- The following organic compounds can go into a drain:

  acetic acid
  acetone
  butanols
  esters with less than 5 carbon atoms
  ethanol
  ethylene glycol
  glycerol
  methanol
  oxalic acid
  pentanols
  propanols
  sodium salts of carboxylic acids
  potassium salts of carboxylic acids
  formic acid
  sugars

  For additional information on drain disposal of substances, see the National Research Council's *Prudent Practices in the Laboratory* (1983).

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- If in doubt about the proper disposal of a chemical, check with the local safety officer or refer to Flinn or a similar reference.

d. **Compounds Not Suitable for Drain Disposal**

For compounds not suitable for drain disposal, label and package the compound and ship by a shipper approved by the U.S. Department of Transportation to a landfill designated by EPA to receive chemical and hazardous waste. Even though packed, shipped, and disposed of by licensed and approved firms, generators of hazardous waste are responsible for the wastes.