

# CHAPTER 11

## Working Safely with Chemicals

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### I. INTRODUCTION TO CHEMICAL SAFETY

Biotechnology laboratories contain a wide variety of chemicals with different health and environmental hazards. It would be an insurmountable task for an individual to memorize all the hazards for each compound. As discussed in Chapter 9, in 1983 OSHA created the Federal Hazard Communication Standard (HCS), which regulates the use of hazardous materials in industrial workplaces. The purpose of this law is to ensure that chemical hazards in the workplace are identified and their risks evaluated, and that this information is communicated to employees. This law requires the employer to:

- identify all chemicals used in the workplace
- have a Material Safety Data Sheet, MSDS, (see Chapter 9) available for each chemical
- label all chemicals
- provide a written program for handling the chemicals
- train employees on the proper use of all chemicals
- provide complete information to health care professionals in emergencies

Chemicals are an integral part of the working environment of the laboratory. All chemicals can be hazardous (e.g., common table salt can be related to high blood

**Table 11.1. GOOD PRACTICES FOR WORKING WITH LABORATORY CHEMICALS**

- Learn about the physical and toxic properties of a chemical before you start working (e.g., by reading the MSDS).
- Minimize the amount of chemical used.
- Handle, store, and dispose of the chemical according to recommended procedures.
- Work only in well-ventilated areas.
- Label all containers with the chemical name and hazard warnings.
- Wear appropriate personal protective clothing.

pressure in some cases; sugar can be hazardous to an individual with diabetes). When handling any chemicals, even those with no known hazards, the best strategy is to use good general laboratory practices, see Table 11.1.

## II. CHEMICAL HAZARDS

### A. Introduction to Hazardous Chemicals

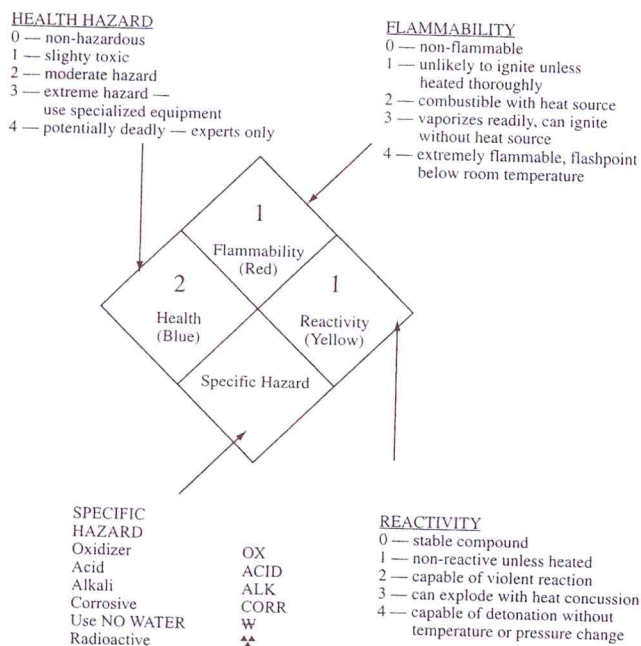
Many chemicals found in laboratories can present risks to users who do not practice good laboratory techniques. A chemical is defined as *hazardous* if:

- it has been shown to cause harmful biological effects
- it is flammable, explosive, or highly reactive
- it generates potentially harmful vapors or dust

In addition, many chemicals are considered potential hazards because of their structural similarities to known hazards, even though no data are available about the chemical itself.

The preceding categories are not mutually exclusive, and many chemicals exhibit more than one of these properties. There are a number of labeling systems that chemical suppliers use to indicate hazards on chemical containers. One of the most widespread is the hazard diamond system developed by the National Fire Protection Association (NFPA). The **hazard diamond system rates chemicals according to their fire, reactivity, and general health hazards**, see Figure 11.1. This system provides easy-to-read, color-coded information with simple numerical scales. Special hazards, such as radioactivity, are indicated by standard symbols.

It is important to have information about the hazards of laboratory chemicals on hand at all times. One excellent resource for laboratories is *Prudent Practices in the Laboratory. Handling and Disposal of Chemicals* (National Research Council, National Academy Press, Washington, DC, 1998), which provides an overview of the issues related to chemical hazards, provides general information about many laboratory chemicals, and also



**Figure 11.1. National Fire Protection Association System for Hazard Classification.** The hazard diamond has four hazard codes to indicate health hazards, flammability, reactivity, and any special hazards. The numerical rating system uses the numbers 0 to 4, with 0 indicating a non-hazard and 4 denoting the highest hazard level of that type. Special hazards are indicated with symbols as shown in the figure. On the sample label shown, the chemical is moderately toxic, only slightly flammable, and unreactive unless heated.

suggests appropriate reference materials for more detailed information. The Hazard Communication Standard requires that a set of MSDSs be available for all chemicals used in a particular workplace. Many laboratories keep their own set in a notebook. MSDS information is also readily available on the Internet (<http://hazard.com/msds/index.html>).

### B. Flammable Chemicals

As discussed in the previous chapter, laboratory fires frequently involve flammable chemicals (Class B fires). **Flammable** refers to materials that are relatively easy to ignite and burn. Note that the term *inflammable* also refers to flammable materials. (The term *nonflammable* is sometimes applied to chemicals that do not readily ignite and burn.) The most common flammable chemicals found in laboratories are liquid organic **solvents**, which are chemicals that dissolve other substances. Many of these liquids are **volatile**, evaporating quickly at room temperature. It is the vapor phase of flammable liquids that burns, not the liquid itself.

*Flammability* is a relative term because all materials can be ignited in the presence of adequate heat. **Flash point** is the temperature where a chemical produces enough vapor to burn in the presence of an ignition source. The lower the flash point, the more flammable

the compound. Many common laboratory chemicals, such as acetone and hexane, have flash points well below  $0^{\circ}\text{C}$ , see Example 1. This means that flammability is always a concern when working with these materials. Once ignition of a flammable solvent occurs, the increasing temperature increases the rate of vaporization, which in turn provides more fuel to burn. Solvent fires can spread out of control very quickly if there is not prompt corrective action. Another concern with flammable liquids is that solvent vapors can diffuse along lab benches or floors, mixing with air and eventually contacting an ignition source. The flames can then follow the invisible vapor trail back to the original container, igniting the larger source of fuel.

### EXAMPLE 1

#### Acetone

Acetone is an example of a relatively nontoxic but highly flammable solvent that is commonly found in biotechnology laboratories. It has a flash point of  $-18^{\circ}\text{C}$  (NFPA Fire Hazard Rating = 3) and it is susceptible to “flash back” because of its volatility (remember the Case Study in Chapter 10, p. 157). The odor of acetone is detectable at concentrations in air well below toxic levels. Acetone can act as an eye and nasal irritant, but these effects are generally short-lived.

There are many systems available for rating the flammability of laboratory chemicals, usually based on their flash points. The NFPA, for example, rates chemicals on a scale of 0–4, with 0 being nonflammable and 4 being extremely flammable. Any chemical with a rating of 3 or 4, which includes those with flash points at room temperature or below, should be treated as a fire hazard. Table 11.2 provides a set of guidelines for handling flammable chemicals to reduce the risk of fire.

Handling chemicals safely depends on knowledge of the properties of individual chemicals. Some powdered metals, for example, are **pyrophoric**, which means that they will ignite on contact with air. Other chemicals (e.g., elemental sodium) react violently on contact with water. These types of chemicals must be manipulated only within a controlled environment. Possibly the most dangerous flammable liquid handled regularly in biotechnology laboratories is diethyl ether, with a flash point of  $-45^{\circ}\text{C}$  (NFPA Fire Hazard Rating = 4). This chemical should never be placed in proximity to electrical equipment that might produce sparks (e.g., centrifuges or regular refrigerators). It should be handled in fume hoods that will prevent a buildup of flammable vapors.

Fire codes require that 10 gallons or more of flammable liquids be stored in safety cabinets that are designed to minimize the risk of fire or explosion, see Figure 11.2. These cabinets do not require venting in the absence of toxic fumes, and the lack of an outside

**Table 11.2. SAFE HANDLING OF FLAMMABLE CHEMICALS**

Standard safety practices as described in Table 11.1, plus:

- Keep all flammable substances away from ignition sources.
- Never heat a flammable chemical with an open flame.
- Remember that solvent vapors can mix with air and diffuse to distant ignition sources.
- Know the appropriate fire prevention methods for the chemical.
- Keep containers tightly closed at all times when not in use.
- Never store incompatible chemicals together (keep acids separate from bases, etc.).
- Keep flammable chemicals away from reactive chemicals.
- Work only in fume hoods or other well-ventilated areas.
- Avoid static electricity discharges when working with flammable substances.
- Never pour flammable substances down a drain or into the trash.
- In case of a spill, deal with any skin contamination before beginning the laboratory decontamination process.

air supply will act as a limiting agent for any fire within the cabinet. If venting is introduced, the cabinet system must be constructed with proper ducts and blowers to vent fumes from the building.



**Figure 11.2. Storage Cabinet for Flammable Chemicals.** (Photo © 2008, Flinn Scientific, Inc. All Rights Reserved. Reproduced for one-time use with permission from Flinn Scientific, Inc. Batavia, Illinois, U.S.A. No part of this material may be reproduced or transmitted in any form or by any means, electronic or mechanical, including, but not limited to photocopy, recording, or any information storage or retrieval system, without permission in writing from Flinn Scientific, Inc.)

## C. Reactive Chemicals

Most laboratory chemicals are reactive to some extent, but those that pose the greatest hazard to laboratory workers are those that undergo violent chemical reactions. Reactive chemicals can be categorized as:

- those that participate in exothermic or gas-generating reactions
- unstable chemicals
- those that form peroxides and other oxidizing agents
- incompatible chemical mixtures

Reactive chemicals may produce an **explosion**, a sudden release of large amounts of energy and gas within a confined area. A fire may result, depending on the elements involved. General guidelines for handling reactive chemicals are provided in Table 11.3.

In a laboratory, explosions are likely to occur as a result of combining reactive chemicals in a sealed container. Sealed containers can also explode if used for any **exothermic** (*heat-producing*) or gas-forming chemical reaction, see the Case Study below. This happens with some regularity in mixed chemical waste containers (which are not recommended). Glass bottles should never be used to contain potentially reactive chemical mixtures.

### CASE STUDY

#### Mixed Waste Containers

A graduate student in one of the author's labs was working late and in a hurry. He needed to dispose of some liquid waste and poured it into a glass bottle, designated for organic wastes, inside a fume hood. Noticing that the bottle was full, he replaced the cap, pulled the hood sash 80% closed, and left the room. Within three minutes the bottle, which contained acid as well as organic waste, exploded from a gas-producing chemical reaction. The sash of the fume hood, which was constructed of shatter-proof material, contained much of the flying glass and liquid within the hood, but was sufficiently damaged to require replacement. Several large pieces of chemically contaminated glass flew under the hood sash, through the open lab door, across the hallway, and into the facing lab—a distance of almost 50 feet. It was fortunate that no one was present in the path of the debris. Cleanup and decontamination took several hours. After the incident, only plastic bottles, with the caps removed from the hood, were used as waste containers.

Some chemicals are unstable and are susceptible to chemical breakdown with time, see Example 2. This is one reason why all chemicals should be labeled with the date of receipt. In some cases, the breakdown products are shock-sensitive. The most commonly encountered examples are picric acid, dinitrophenol, and compounds that break down into organic peroxides.

**Table 11.3. SAFE HANDLING OF REACTIVE CHEMICALS**

Standard safety practices as described in Table 11.1, plus:

- Know the reactive properties of the chemical (read the MSDS).
- Never mix unknown chemicals together, especially in closed waste containers.
- Label containers of reactive chemicals carefully.
- Store only compatible chemicals in the same area.
- Store oxidizing chemicals away from flammable materials.

A **peroxide former** is a chemical that produces peroxides or hydroperoxides with age or air contact. These chemicals, which include a variety of aldehydes, ethers, and ketones, are highly hazardous. They are flammable and may explode on exposure to heat or shock. It is important to refer to the MSDS for information about the hazards of specific chemicals.

### EXAMPLE 2

#### DEPC (Diethyl Pyrocarbonate)

Diethyl pyrocarbonate (DEPC) is a toxic chemical commonly found in biotechnology laboratories. It is used to treat solutions and glassware when isolating RNA because it is an effective agent for inactivating RNA-digesting enzymes. It is also a suspected carcinogen, and should be handled only with gloves. In addition, DEPC breaks down to carbon dioxide gas and ethanol when exposed to moist air. If this decomposition takes place in a sealed bottle, pressure can build to explosive levels. DEPC should be stored under dry conditions in a refrigerator, within a desiccator. If possible, store the bottle in the original metal container to act as an explosion barrier. Always allow refrigerated DEPC to equilibrate to room temperature before opening the bottle. Because DEPC is an explosion hazard, always use goggles and a shield when handling a stock bottle.

Peroxide formation is generally limited to liquids that have evaporated and undergone autooxidation. Diethyl ether and tetrahydrofuran (THF) are the most likely peroxide formers to be found in biotechnology laboratories. These chemicals should be stored away from light and heat in carefully sealed containers. Any containers that show signs of evaporation, especially older containers of ether, should not be handled. Contact your institutional safety office for proper disposal instructions.

In addition to the preceding hazards, certain combinations of chemicals can undergo violent reactions that result in explosions or release of highly toxic gases or other products. The best protection against this phenomenon is to follow standard laboratory procedures