2

Safety First

2.1 Introduction

The laboratory is a hazardous environment, period. Not taking this fact to heart is a foolish endeavor, a real danger to co-workers and community and detrimental to the environment. Wine laboratory personnel not only face the dangers often found in the laboratory but also the dangers lurking in the cellar and on the bottling lines. Safety must always be in the forefront of your mind, a conscience everyday practice. Know what hazards exist in your workplace, how to avoid danger, and how to respond to an accident. Making safety first can save lives.

Safety and the preservation of a healthy workplace is the moral obligation of every laboratory worker, chemist, supervisor, department head, winery president or CEO, local government, state government, and the federal government. Laws and regulations have been developed to ensure a safe workplace, and these laws require mandatory safety rules and programs making safety a lawful obligation.

The economic impact of accidents in the workplace directly affects all employees. Businesses lose millions of dollars each year due to on-the-job accidents, directly affecting the profitability of a company. These losses add up to higher insurance rates for employees and reduces the ability of companies to grow and compensate employees. Everyone loses.

Despite the abundance of regulations, information, and safety procedures available to employers and employees, a high number of accidents still occur. Unfortunately, most accidents are due to the "can't happen to me" attitude, "skipping" procedural steps, sloppy technique, and just not thinking.

Ultimately, being safe is everyone's responsibility. This chapter is an introduction to basic safety in the wine laboratory and cellar.

2.2 Regulatory Agencies and Acts

Every aspect of the work environment is addressed and regulated by a specific organization via legislative guidelines focused on human health and protection of the environment.

The Occupational Safety and Health Act (OSHA citation 29, USC 651 et seq.) is enforced by the Occupational Safety and Health Administration, the primary national regulatory body instituting and monitoring set regulations and guidelines for safety in the workplace. OSHA outlines the recognition and evaluation of potential hazards, prevention or control of hazards, and training of employees to understand and know how to protect themselves and others from hazards.

The Environmental Protection Agency (EPA) enforces several pieces of legislation dealing with environmental issues:

- The Resource Conservation and Recovery Act (RCRA citation 42 USC 6901 et seq.) sets guidelines for chemical waste and the protection of groundwater and soil contamination.
- The Superfund Amendments and Reauthorization Act (SARA citation 42 USC 9601 et seq. and 11000 et seq.) sets regulations for emergency planning and reporting of hazardous materials.
- The Toxic Substances Control Act (TSCA citation 15 USC 2601 et seq.) is concerned with the testing and restrictions of certain chemical substances.
- The Clean Air Act (CAA citation 42 USC 7401 et seq. and 7409 et seq.) protects air quality by controlling emissions of ozone and air pollutants.
- The Federal Water Pollution Control Act (FWPCA citation 33 USC 1251 et seq.) protects water quality with the regulation of substances discharged into public waters.

The US Department of Transportation (DOT) is the regulatory body for the Hazardous Materials Transportation Act (HMTA citation 49 USC 1801 et seq.), which controls the movement of hazardous materials by regulating packing, labeling, transportation, and education of transport personnel.

Every company and facility is required to have a safety program geared for the winery size, number of employees, and degree of hazard. The safety program should include a chemical hygiene plan as outlined in the OSHA's laboratory standard (29 CRF 1910.1450).

Violation of the OSHA safety laws and regulations has grave consequences. Serious violations where severe injury or death could occur can carry fines in a range from $100 to $7000 per violation. Willful violations by an employer can carry fines up to $70,000 per violation. If a violation results in the death of an employee, fines for a first offense can reach $500,000 for a company and $250,000 for an individual or a jail sentence of 6 months—and in some cases, both.

Workplace safety information and guidelines to prepare and initiate a safety program and chemical hygiene plan are readily available and can be obtained from government and local organizations by contacting them directly or through the Internet.

2.3 Laboratory and Winery Hazards

Common laboratory and winery hazards are listed in Table 2.1. Chemical hazards are dangers that are inherent to a chemical and the potential risks associated by handling, storage, and use of the chemical. Physical hazards are dangers that are inherent to an operation or action posing a potential risk associated by carrying out the operation or action. Be aware of potentially dangerous situations and evaluate the risk potential in each job you perform.

Each laboratory and facility should have an active emergency response system in place to address any emergency that might arise and to reduce and contain losses of property and injury to employees. This emergency plan should include contingencies for evacuation, fires, chemical spills, earthquakes, accidents, and injury. Training all employees in fast-response emergency action is required. OSHA's 29 CFR 1910.38 standard delineates the elements required for an emergency response plan.

TABLE 2.1. Common winery hazards.

Laboratory

Chemical hazards

- Carcinogens
- Toxic compounds
- Irritants
- Corrosive substances
- Allergens
- Reproductive toxins
- Developmental toxins
- Flammable substances
- Reactive substances
- Explosive substances
- Asphyxiates

Physical Hazards

- Compressed gases
- Cryogens
- Vacuum
- Electrical
- Explosion
- Cuts
- Slips
- Trips
- Falls
- Burns
- Strains
- Punctures
- Fire

Winery Cellar

Chemical hazards

- Corrosive substances
- Allergens
- Irritants
- Flammable substances
- Asphyxiates

Physical Hazards

- Compressed gases
- Cryogens
- Microwaves
- Electrical
- Cuts
- Slips
- Trips
- Falls
- Burns
- Truck traffic
- Equipment failure
- Forklifts
- Explosion
- Drowning
- Entanglement
- Fire
- Crushing
- Punctures
- Strains
- Abrasions

2.4 Chemical Hazards

Before touching any chemical, it is essential to educate yourself on the handling and use of the chemical. All chemical companies and distributors are required to provide information sheets on each chemical shipped to protect the user from possible hazards; they are called Material Safety Data Sheets (MSDS). MSDS contain information about the chemical's properties, health hazards, National Fire Protection Agency (NFPA) ratings, storage, disposal, transportation, neutralizing agents, personal protection equipment, extinguishing media, ecological information, and emergency first aid procedures. Few companies supply complete MSDS with all the necessary information you require. Some sections might have the statement "I/A/W (in accordance with) ALL FEDERAL, STATE, and LOCAL REGULATIONS," which means that you will need to find out what those regulations are on your own. It might take looking at several MSDS from different companies to compile all the information you require, or going directly to the regulatory agencies for clarity. MSDS for chemicals used in the laboratory are required to be readily accessible to all employees.

Another source of information is the Laboratory Chemical Safety Summaries (LCSS). The LCSS is directed specifically toward the laboratory worker providing similar information found in the MSDS but with additional information that directly affects the handling of the chemicals in the laboratory setting (see the Appendix).

2.4.1 Toxic Chemicals

It is a good rule of thumb to assume that no chemical is safe. The risks associated with a chemical are based on the toxicity of the chemical itself, or when combined with other chemicals, and the degree of exposure. The degree of exposure is dependent on the quantity of chemical contact (dose), for how long (duration), how often (frequency), and route of exposure.

Toxic chemicals produce local effects, systemic effects, or both, and are classified by the toxic response in the body: irritant, neurotoxin, corrosive, allergen, asphyxiant, carcinogen, or reproductive and developmental.

2.4.1.1 Dose, Duration, Frequency, and Routes of Exposure

Dose response is the relationship of the quantity of chemical exposure and the effect it produces. As an example, a 2-mg dose of a substance might have no effect and a 2-g dose of the substance might create vomiting; however, a 25-g dose of the substance causes death. It does not matter what the substance is, if enough of the substance is introduced into the body, there will be toxic results.

Lethal concentration 50 (LC_{50}) or lethal dose 50 (LD_{50}) is an indicator of the level of chemical toxicity. The LC_{50} is determined in a controlled environment using test animals. A group of animals are exposed to various dosages of a chemical via inhalation, direct contact, ingestion, or injection. The dose of chemical that is given that kills 50% of the animals is noted as the LC_{50} and is expressed in grams per kilogram of body weight. Toxicity ratings are generally accepted as follows (National Research Council, 1995):

- Extremely toxic = LD_{50} <5 mg/kg
- Highly toxic = LD_{50} <50 mg/kg
- Moderately toxic = LD_{50}=50–500 mg/kg
- Somewhat toxic = LD_{50}=500 mg/kg to 5 g/kg
- Virtually nontoxic = LD_{50} >5 g/kg

Volatile chemicals are reported as LD_{50} and expressed in parts per million (ppm), milligrams per liter (mg/L), or milligrams per cubic meter (mg/m^3).

Chemical toxicity can occur immediately upon contact with a chemical or upon repeated or chronic exposures. Chronic exposure to low-dose toxins is particularly dangerous due to their cumulative effects in the body that might not be apparent for many years. The duration and limits of exposure to toxic chemicals have been established by the American Conference of Governmental Industrial Hygienists (ACGIH) and OSHA.

Inhalation is the number one mode of chemical exposure in most laboratories. Inhalation of toxic materials poisons the body by absorption through the mucous membranes via the nose, mouth, throat, and lungs or by passing into the capillaries of the lungs into the bloodstream.

Threshold limit value (TLV) (ACGIH) and permissible exposure limit (PEL) (OSHA) are analogous terms identifying the concentration of chemical in the air that produces no adverse effects.

The ACGIH has set TLV using two different time frames (National Research Council, 1995):

- TLV–TWA = threshold limit value – time-weighted average; delineates the limit of safe chemical exposure in an 8-h workday for a 40-h workweek.
- TLV–STEL = threshold limit value – short-term exposure limit; used for higher concentrations of chemical indicating the amount of chemical exposure that is safe for a 15-min period.

Workers can be exposed to a maximum of four STEL periods per 8-h shift, with at least 60 min between exposure periods. It is recommended that a fume hood be utilized when using a chemical with a PEL or TLV less than 50 ppm.

Direct skin or eye contact with a toxic chemical is a frequent route of exposure in the laboratory. Skin irritations and allergic reactions are more frequent with direct exposure to a variety of chemicals. Corrosive chemicals might cause severe burns at the point of contact. Chemicals can enter the body through the skin's glands, follicles, cuts, or abrasions, causing systemic toxicity.

Ingestion of toxic chemicals happens. Food eaten in the laboratory can be contaminated by chemicals found on work gloves or eating food that has been in contact with laboratory benches. The chemical might cause contact tissue damage throughout the gastrointestinal (GI) tract, be absorbed through the GI tract into the bloodstream causing systemic damage, or both.

Direct injection of toxic chemical into the bloodstream is the fastest way to introduce a toxic chemical into the body. Most often this occurs with contaminated broken glass cutting into the skin. Some types of laboratory equipment with sharp parts and needle assemblies can also create an injection injury.

2.4.1.2 Classification of Toxins

Chemicals producing a reversible inflammation at the contact site are called *irritants*. Direct contact with the chemicals in this category should be avoided.

Corrosive substances are the most common toxic chemicals found in a wine laboratory and cellar. These substances can come in the form of a liquid, solid, or gas. Corrosive substances react chemically at the contact site, destroying living tissue. Corrosive substances include strong acids, strong bases, and strong dehydrating agents. Examples of common corrosives are hydrochloric acid, phosphoric acid, sulfuric acid, sodium hydroxide, concentrated hydrogen peroxide, nitrogen dioxide, and sulfur dioxide.

Allergic responses can occur with exposure to a toxic chemical after initial sensitization of the immune system. The reaction can range from itchy skin to anaphylactic shock, depending on an individual's level of sensitivity. Some people with high sensitivity can react adversely to the smallest dose, whereas others will have no reaction to a large dose of the same chemical. Reactions can be immediate or delayed for hours or days.

The winery cellar uses a variety of gases to prevent oxidation in wine and as an antimicrobial agent for wine and juice. Nitrogen, argon, sulfur dioxide, and carbon dioxide are the gases most frequently used due to their ability to displace oxygen, thus producing an anoxic environment in the tanks or barrels. Carbon dioxide gas is also naturally produced during juice fermentation. Tanks and cellars that have a lack of breathable oxygen can render a person unconscious and lead to death by asphyxiation. Asphyxiation is the most common cause of death in a winery.

Carcinogens are cancer-producing substances and are highly toxic. Most of these substances affect the body after repeated or extended exposure, with no indication of effects for many years. Chronic exposure can stimulate the uncontrolled growth of cells in an organ and some chemicals can directly affect the cell DNA.

Reproductive and developmental chemical toxins adversely affect the entire reproductive process. There are developmental toxins called *teratogens* that cause developmental malformations or death in a developing embryo or fetus and *mutagens* that cause chromosomal damage with an increase in the frequency of cellular mutations in an embryo or fetus. Fetus growth can be retarded by some developmental toxins as well as creating postnatal functional deficiencies. Reproductive toxins can render the user, male or female, sterile. Cycloheximide (Actidione) is a developmental toxin used by wine laboratories as a standard bactericidal ingredient in selective microbiological plating media.

Neurotoxins adversely affect the central nervous system (CNS) of the body by altering its structure or function. A large number of neurotoxins are chronically toxic due to their long latency periods and most neurotoxins can be most difficult to diagnose. Further investigation of neurotoxins is being conducted to improve early detection.

2.4.2 Reactive Chemical Hazards

Chemicals pose a serious risk due to their reactive natures. They can be flammable and explosive or create intense reactions.

Flammable chemicals can be a gas, liquid, or solid that can ignite and burn in the presence of oxygen. Highly flammable denatured alcohol is used frequently in the laboratory as a fuel source in open-flame burners. The alcohol burns readily by itself but it is more dangerous due to its rapid vaporization. If there is a buildup of vapor due to poor ventilation, the vapor can ignite and enflame the source.

Volatility indicates the ease with which a liquid or solid will pass into the vapor stage and is measured by the chemical's boiling point. The flash point of a chemical is the lowest temperature at which a liquid can form enough vapor pressure to ignite in the presence of air when exposed to a flame. Chemicals with flash points of 38°C or below are the most dangerous. The ignition temperature is the point at which a substance reaches self-sustained combustion without a source of heat or spark; the chemical will simply autoignite.

Information concerning the flammability, flash-point temperatures, and ignition temperatures of chemicals dictate how a chemical should be handled and stored, what precautions to take while working with the chemical, and what safety equipment is required in case of an accident.

The rate of vaporization, the ability to form combustible mixtures with air, and the ease of ignition dictate the level of fire danger associated with a chemical. The NFPA classifies flammable chemicals according to their degree of hazard and has developed a system that incorporates this information in conjunction with health hazards, reactivity levels, and other specific hazards associated with chemicals. The NFPA classifications will be discussed later in this chapter. Table 2.2 lists the NFPA fire hazard rating, flash point, boiling point, and ignition temperature of a few chemicals that could be found in the wine laboratory.

TABLE 2.2. Chemical flammability.

	NFPA rating	Flash point	Boiling point	Ignition temperature
Acetic acid (glacial)	2	39°C	118°C	463°C
Acetone	3	−18°C	56.7°C	465°C
Ethyl alcohol	3	12.8°C	78.3°C	365°C
Hydrogen	4	—	−252°C	500°C
Isopropyl alcohol	3	11.7°C	82.8°C	398°C

Note: 0 = will not burn; 1 = must be preheated to burn; 2 = ignites when moderately heated; 3 = ignites at normal temperature; 4 = extremely flammable.

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The combination of certain chemicals by accident or design can result in potentially dangerous situations due to the intensity of the reaction. Low-intensity reactions might produce a slight increase in the temperature of the chemical mixture, whereas a high-intensity reaction might create an explosion.

It is important to know the classes of chemicals, chemical compatibility, and what *not* to combine in a noncontrolled reaction. The major risk lies in the storage of chemicals where accidental spills of two or more chemicals in large quantities can have devastating consequences. Disasters such as earthquakes, fires, floods, and tornadoes could lead to the damage of chemical storage containers, creating a potential reactive hazard. Table 2.3 is a partial listing of chemicals commonly found in the wine laboratory and the chemicals that are incompatible with them. An excellent reference with additional listings of incompatible chemicals can be found in L. Bretherick's 1986 *Hazards in the Chemical Laboratory,* 4th edition, Royal Society of Chemistry, London, England.

Water can react violently with groups of chemicals, creating tremendous heat that could lead to an explosion or fire. Pyrophorics are substances that when combined with the moisture in the air or oxygen react so fast that the mixture can ignite. Extremely reactive chemicals can begin a rapid reaction by a spark, movement, heat, catalyst, or detonation that will create a violent expansion of gases, heat, and noise. Peroxides, oxidizing agents combined with reducing agents, and auto-oxidative compounds could have explosive tendencies. Explosive chemicals need very special handling, storage, and safety precautions.

2.4.3 Chemical Handling and Storage

Because of to hazards handling chemicals, it is important to institute strict guidelines for every aspect of chemical contact. These guidelines must be accessible to all receiving and warehouse personnel, cellar workers, and laboratory personnel. Key elements to safe handling of chemicals include the following:

TABLE 2.3. Incompatible chemicals.

Chemical	Incompatible chemicals
Acetic acid (glacial)	Alcohols, hydrogen peroxide, ethanolamine, alkali hydroxides, chlorates, chromic acid, carbonates, peroxides, permanganates, metals, aldehydes, anhydrides, ethylene glycol
Acetone	Concentrated nitric and sulfuric acid mixtures, hydrogen peroxide
Calcium carbonate	Acids, fluorine gas, ammonium salts
Carbon (charcoal) activated	Calcium hypochlorite, other oxidants
Carbon dioxide	Alkali metals
Chromic acid	Acetic acid, naphthalene, camphor, alcohol, turpentine, glycerol, other flammable liquids
Copper(II) sulfate	Hydrogen peroxide, acetylene, hydroxylamine, strong reducing agents
Cycloheximide	Strong peroxides, hydrogen peroxide, oxidizing agents; strong acid chlorides, acid anhydrides, alkali, bases
Ethyl alcohol	Peroxides, acids, acid chlorides, acid anhydrides, alkali metals, ammonia, moisture, strong oxidizing agents
Ethylene glycol	Strong bases, perchloric acid, strong acids, chlorosulfonic acid, acetic acid, strong oxidizing agents
Hydrogen peroxide 3%	Copper, rust, brass, zinc, nickel, iron, most metals or their salts, alcohols, acetone, strong oxidizers
Hydrochloric acid (concentrated)	Metals, amines, metal oxides, vinyl acetate, formaldehyde, alkalis, carbonates, strong bases, sulfuric acid
Hydroxides (alkali and alkaline earth metals)	Acids, water, carbon dioxide, hydrogen peroxide, nitro compounds, metals, oxidizing agents, ammonium compounds, chlorinated hydrocarbons
Iodine	Acetylene, ammonia (anhydrous or aqueous), ammonium hydroxide, strong reducing agents, some metals
Malic acid	Bases, strong oxidizing agents, reducing agents, alkali metals
Mercury	Acetylene, nitric acid/ethanol mixtures, ammonia, boron, metals, oxygen, ethylene oxide, oxidants
Oxygen	Oils, grease, hydrogen, flammable liquids, solids, gases
Ozone	Reducing agents, combustible materials
Sodium thiosulfate	Mercury, iodine, strong acids and oxidizing agents
Sulfuric acid (concentrated)	Water, metals, combustible materials, bases, perchlorates, permanganates, chlorates, hydrogen peroxide, oxidizing agents, strong reducing agents
Sulfur dioxide	Zinc, aluminum, iron oxide, sodium, strong reducing agents, chlorates, hydrogen peroxide, strong oxidizing agents,
Tartaric acid	Bases, silver and silver salts, oxidizing agents, reducing agents
Triethanolamine	Acids, peroxides, oxidizing agents

Note: This is a partial listing.

- Ordering and receiving
- Proper labeling
- Chemical compatibility
- Proper storage

2.4.3.1 Ordering and Receiving

Ordering chemicals requires a complete understanding of the types of analysis performed in the laboratory, the quantity of chemicals used in a given time frame, the location and amount of storage available, storage risks, and economic factors.

You never want to run out of chemical for any given assay, but you also do not want a large supply on hand that might reach its expiration date before it has been used. If a facility or company has several laboratories, check with the other locations before you order. They might have excess stock that can be transferred. Keeping a 1-month supply on hand seems to work well. Most chemicals have approximately a 1–2-week lead time, which is the time it takes to order and receive the product. Suppliers can let you know how far in advance to order and the availability of the chemicals you use. This method prevents old chemicals from accumulating, it requires less storage space, and smaller quantities equal less safety risks, less chance of contamination, and little or no waste. Large quantities are less expensive, but if they expire or are unused, the cost of disposing of those chemicals could be very high. Chemicals with long shelf lives that must be ordered in larger quantities should be stored safely with strict attention to expiration dates.

Request the chemical supplier to include the MSDS with each shipment. An MSDS binder with all MSDS listings should be kept up-to-date and located in the receiving departments, cellar, and, of course, the laboratory. Keeping up-to-date MSDS information is critical, and when included with each shipment, it assists receiving personnel in handling a leaking package quickly.

Upon delivery of chemicals in the receiving department, the appropriate person or laboratory should be notified immediately. Some chemicals will require special storage such as refrigeration and need attention as soon as they arrive. Advising receiving of expected chemical shipments will expedite the receiving process. After proper notification, the chemicals should be set aside in a safe area away from other materials until they are picked up or delivered.

Small packages should be carried with both hands; larger or heavy packages should be placed on a cart for transport. If the chemical is moderately to highly toxic or has a glass container, place the package in an unbreakable secondary containment vessel such as a chemical-resistant bucket or pan large enough to contain the entire volume of chemical plus the container and transport via cart. It is against most companies' policies to transport chemicals in personal vehicles. If transporting chemicals in a vehicle, secondary containment must be provided in the event of a spill, especially with a liquid or chemicals in glass containers. The containment vessels should be secured to the vehicle to prevent movement during transportation.

Receiving gas cylinders in the cellar, laboratory, or receiving area requires cautious handling. Cylinders must be secured, with caps on, and transported on a cylinder cart, never dragged or rolled (see Fig. 2.1). Some liquid gas cylinders, such as a Dewar, can be mounted on heavy-duty wheels for ease of transportation. Placing the order for gas cylinders should include a request for safe transport via cylinder carts. If a supplier fails to conform to the request, refuse the order and find another supplier. Use a gas supplier that will not only deliver but pick up the empty cylinders.

2.4.3.2 Proper Labeling

A chemical inventory sheet or database listing the chemical's proper name, Chemical Abstract Service (CAS) registry number, hazard information, stor-

FIGURE 2.1. Gas cylinder and transportation cart.

age location, date received, date of expiration, and supplier is helpful for the laboratory staff, is a quick reference in locating chemicals, and, in some communities, is required. Check with local authorities for their requirements. Keeping a copy of the inventory sheet at all storage locations is helpful as a quick guide in the event of a spill.

Receiving chemicals into the laboratory for storage or immediate use requires time to properly complete paperwork, properly label the containers, and, in some cases, properly place warning signs. Chemical labeling and storage can prevent dangerous situations, so be thorough. This is not a place to save time.

Before opening the package, compare the order to the shipping information. Compare the chemical name, registry number, catalog number, and concentration of the chemical. If correct, look for any damage or leaks and open shipping packages carefully.

Check the labels of the containers and replace torn or damaged labels. Do not accept containers that have no labeling. Contact the chemical supplier immediately upon receipt of damaged or unlabeled chemicals. Each container should have the name of the chemical, molecular formula, CAS registry number, concentration, NFPA hazard classification, and expiration date.

It is good safety practice to affix an NFPA label to chemical containers being stored and chemical containers used in the laboratory. Labels can be made or purchased from a safety supply company. Figure 2.2 (see Color Plate 1) outlines the NFPA hazard classification method used to identify chemicals.

2.4.3.3 Proper Storage

Before storing chemicals, pay strict attention to the NFPA hazard rating, the chemical compatibility, stability, and storage information located on the MSDS, and general OSHA guidelines (OSHA, 29CFR 1910.1450). Avoid storing chemicals on benchtops, on tops of cabinets, ventilation hoods, in drawers, in cleanup/wash areas, in high-traffic areas, and in office areas. When possible, store chemicals in unbreakable containers and use unbreakable containers for benchtop work. Refrigerated chemicals should be stored in a labeled "chemicals only" refrigerator where they will not be in contact with food items. Odiferous chemicals should be stored in a ventilated cabinet, but if such a cabinet is not available, store them in a sealed container. Chemicals should be stored away from extreme temperatures and sunlight.

Store the chemicals in compatible groups. They can occupy the same chemical cabinet but different shelves. Secondary containment is recommended for storage cabinets and benchtop working containers. A few examples of compatible groups are as follows:

- Acids
- Bases
- Flammable liquids
- Alcohols, glycols
- Hydrogen peroxide, hypochlorites
- Hydroxides, carbon, carbonates
- Sulfur, phosphorus
- Sulfates, sulfites, thiosulfates, phosphates
- Chromates, permanganates

It is good common practice to rotate your chemical stock (or any stock item) by dating each container with the date received. Place the newly received chemical containers behind the current stock, making it easier to use the oldest chemicals first. To avoid hazards and problems, check chemical expiration dates frequently and properly dispose of expired chemicals.

Before using a chemical, refilling lab containers, or refilling benchtop working containers, always double check the container for the name and concentration of the chemical. The use, or refilling of a container, with the wrong chemical or chemical concentration is a very common accident in the laboratory and all laboratory personnel must make checking and rechecking second nature. Color coding the working chemical containers and stock containers can make replenishing faster, but it perpetuates the bad habit of not reading and verifying the chemical name and concentration.

Check gas cylinders for proper labeling; never depend on color coding. Flammable, toxic, or corrosive gases are coded with a yellow background and black letters. Inert gases are coded with a green background and black letters. Cylinder storage in earthquake zones requires securing them to a wall with two straps or chains. A single chain or strap is sufficient for other zones. It is best to check your local OSHA and NFPA regulations. Dewars or liquid gas cylinders with wheels must also be secured to a wall to prevent movement in an earthquake. Gas cylinder storage follows the same rules as other chemicals: separate according to compatibility; store separate from other chemicals; when not in use, remove regulators and replace the cap; and segregate empty from full cylinders. It is wise to avoid transport of full cylinders in public elevators.

Cylinders of flammable gases should always be grounded to prevent static electricity buildup. Do not empty a compressed gas cylinder below 25 psi. At this pressure, ambient air could migrate into the cylinder if the valve is left open, requiring notification of the supplier. It is also good practice to remove a cylinder from a closed system while the gas pressure in the cylinder is still higher than the system pressure.

Flammable liquids have flash points less than 100°F (38°C) and must be stored away from heat and any ignition source. Combustible liquids have flash points above 100°F (38°C). Underwriters Laboratory (UL) in conjunction with the NFPA Code No. 30 regulates the manufacturing of flammable and combustible chemical storage cabinets. Flammable storage cabinets or metal safety cans are required for all flammable chemicals. All flammable and combustible chemicals contained in a cabinet must be compatible. Do not store paper, cardboard, or other flammable materials in the same cabinet. Follow the NFPA guidelines for maximum allowable volumes of flammable liquids in the laboratory and in the facility.

The NFPA classifications are as follows:

- Class I Flammable—flash point below 38°C
- Class II Combustible—flash point of 38–60°C
- Class IIIA Combustible—flash point of 60–93°C
- Class IIIB Combustible—flash point above 93°C

Highly toxic chemicals can have extreme storage requirements such as explosion-proof cabinets or cabinets ventilated to a scrubber that will contain toxic fumes.

2.4.4 Chemical Waste

Solid waste is defined by the EPA as discarded materials including solids, semisolids, liquids, and contained gaseous materials; garbage; or sludge. It is prudent practice to evaluate all chemical assays performed in the laboratory, the amount of waste generated from those assays, and understand the chemical characteristics and possible hazards. It is the responsibility of waste generators to determine the type of hazardous waste produced and to properly dispose of it. Consult the EPA's interpretation and lists of hazardous waste (RCRA 40 CFR 261) as well as the local and state regulations to determine if the waste is regulated as hazardous, and if so, in what hazard classification. Most states operate their own hazardous waste programs and may have more stringent regulations and hazardous waste identification criteria than federal regulations.

2.4.4.1 Classification

Classification of EPA listed hazardous waste is broken into five categories (generalized):

1. F (RCRA 40 CFR 261.31)—nonspecific waste (e.g., reaction waste, processing waste)
2. K (RCRA 40 CFR 261.32)—waste from particular industries
3. U (RCRA 40 CFR 261.33)—unused pure or commercial-grade formulations of chemical
4. P (RCRA 40 CFR 261.33)—unused pure or commercial-grade formulations of acutely toxic chemical (highly toxic having an LD_{50} less than 50 mg/kg)
5. D (RCRA 40 CFR 261, Subpart C)—waste not listed above but exhibits hazardous waste characteristics

Hazardous waste characteristics are described by the EPA as follows:

- Ignitable (I) (RCRA 40 CFR 261.21)—flash point of less than 140°F (60°C) or other characteristics that could potentially cause a fire
- Corrosive (C) (RCRA 40 CFR 261.22)—liquids that have a pH of 2 or less (acid) or a pH of 12.5 or greater (base).
- Reactive (R) (RCRA 40 CFR 261.23)—substances that are unstable, react violently with water, could possible detonate, or are a sulfide or cyanide-bearing waste.
- Toxic (T) (RCRA 40 CFR 261.24)—materials that do not pass the Toxicity Characteristic Leaching Procedure (TCLP), which measures the amount of toxic material leached from waste materials where the leachate from the waste is likely to release toxins into the groundwater

The wine laboratory normally generates very little hazardous waste (much less than 100 kg of hazardous waste in 1 month) and is considered exempt from formal management program requirements. If a facility produces more than 100 kg of hazardous waste, consult RCRA 40 CFR 262. Typical hazardous waste found in the wine laboratory include acids, bases, mercury, ethanol, iodine, and denatured alcohol.

2.4.4.2 Waste Disposal

When waste has been classified, the method of disposal can be determined. The method chosen is dependent on the type of chemical or material hazard, amount of generated waste, and economics. Neutralization of certain chemicals is a method used to reduce the hazards of a chemical prior to disposal. This allows stronger chemicals to be disposed of easily and safely. Information and guidelines concerning methods of neutralization can be found in *Prudent Practices in the Laboratory, Handling and Disposal of Chemicals* (National Academy of Science, Washington, DC, 1995).

Incineration of lab waste is carried out by an RCRA-approved treatment, storage, and disposal facility (TSDF). This is one of the most widely used and expensive methods for the destruction of hazardous waste. Contact your TSDF for instructions on waste preparation for this method of disposal.

The laboratory trash receptacles can accept a large number of laboratory wastes. Larger quantities of chemicals should be in unbreakable containers, there should be no free-flowing liquid or broken glassware, and powders should be in containers. Contact the local municipal agency for any restrictions.

Release of hazardous vapors from volatile chemicals into the atmosphere through an exhaust system is allowed if the exhaust is fitted with the proper traps.

The sewer system is one of the most common wine laboratory methods of waste disposal. Substances that can go down the drain must be water soluble and approved by the local sewer facility and public-owned treatment works (POTW): biodegradable aqueous solutions; inorganic solutions; and corrosive and ignitable wastes that are 1% or less of the total wastewater, or 1 ppm of total wastewater generated by the facility. The waste should flow into the sewer system—never into storm drains or septic systems—and be compatible with the piping material. Flushing the system with water after disposal is required and it is suggested that a 100 : 1 ratio of water to chemical be used to keep the chemical levels low in the sewer system. Some chemicals might require predilution before disposal and flushing.

Hazardous waste that requires off-site disposal via an RCRA-approved TSDF should be collected and contained in a proper chemical-resistant package. The package label should contain the name of the substance, CAS number, concentration, physical description (solid or liquid), and any hazard information. If there is a mixture of substances, list all of the above plus note the percentages of all chemicals (contact your specific TSDF for instructions). Labeled waste packages should be placed in clearly labeled chemical-resistant storage containers containing compatible waste (e.g., flammable, corrosive) and stored in an area where they will not be disturbed. A listing of all waste contained within a storage container should be attached to the container and kept current. Laboratories are allowed to keep up to 55 gallons of hazardous waste (or 1 qt acutely hazardous waste) indefinitely, but it is recommended that waste not be held from more than 1 year.

Table 2.4 lists common laboratory chemicals, their classification, and common recommended waste disposal according to various MSDS information. Check MSDS and always confirm with all regulatory agencies to assure compliance. Chemical containers ready for discard that retain a small amount of chemical and the residue from chemical spills might have more rigid disposal requirements, so check with RCRA 40 CFR 261.33.

TABLE 2.4. Chemical transportation and waste disposal.

Laboratory chemical (small quantities)	DOT hazard classification NFPA rating[a]	Common disposal methods[b]
Acetic acid (glacial) CAS# 64-19-7	DOT: Class 8 Corrosive Class 3 Flammable NFPA: H3, F2, R0, S-CORR	**Undiluted**: Contact approved disposal facility **Diluted**: Small quantities dilute to <1 %, neutralize, flush with copious amount of water to sewer
Calcium carbonate CAS# 471-34-1	DOT: Not regulated NFPA: H1, F0, R0	**Undiluted**: Contact approved disposal facility for landfill burial **Diluted**: Small quantities dilute to <1%, flush with copious amount of water to sewer
Chromic acid CAS# 1333-82-0	DOT: Class 8 Corrosive NFPA: Estimate H4	**Undiluted and diluted**: Hazardous waste ID-D007, contact approved disposal facility for landfill burial, reduce/neutralize

TABLE 2.4. (*Continued*)

Laboratory chemical (Small Quantities)	DOT hazard classification NFPA rating[a]	Common disposal methods[b]
Copper(II) sulfate CAS#7758-99-8	DOT: Class 9 Miscellaneous Hazard NFPA: H2, F0, R0	**Undiluted**: Dilute to <1% **Diluted**: Dilute to <1%, flush with copious amount of water to sewer
Cycloheximide CAS# 66-81-9	DOT: Class 6.1 Poison NFPA: Unavailable	**Undiluted and diluted**: Contact approved disposal facility for incineration
Ethyl alcohol CAS# 64-17-5	DOT: Class 3 Flammable NFPA: H2, F3, R0 Estimated	**Undiluted**: Contact approved disposal facility for incineration **Diluted**: Small quantities dilute to <1%, flush with copious amount of water to sewer
Ethylene glycol CAS#107-21-1	DOT: Class 3 Flammable Class 6.1 Poison NFPA: H2, F1, R0	**Undiluted**: Contact approved disposal facility for incineration **Diluted**: Small quantities dilute to <1%, flush with copious amount of water to sewer
Hydrochloric acid (concentrated) CAS# 7647-01-0	DOT: Class 8 Corrosive NFPA: H3, F0, R0, S-CORR	**Undiluted**: Contact approved disposal facility for disposal **Diluted:** Small quantities dilute to <1%, neutralize, flush with copious amount of water to sewer
Hydrogen peroxide 3% CAS# 7722-84-1	DOT: Not regulated NFPA: H1, F0, R1	**Undiluted**: Dilute to <1% **Diluted**: Dilute to <1%, flush with copious amount of water to sewer
Iodine CAS# 7553-56-2	DOT: Class 5.1 Oxidizer Class 6.1 Poison NFPA: H3, R0, R1, S-OX	**Undiluted**: Contact approved disposal facility for disposal **Diluted:** Small quantities dilute to <1%, flush with copious amount of water to sewer
Malic acid CAS#617-48-1	DOT: Not regulated NFPA: H1, F1, R0	**Undiluted**: Contact approved disposal facility for incineration **Diluted**: Small quantities dilute to <1%, flush with copious amount of water to sewer
Mercury CAS# 7439-97-6	DOT: Class 8 Corrosive Class 6.1 Poison NFPA: H3, F0, R0	**Undiluted**: Hazardous waste ID-U151, contact approved disposal reclamation center
Phosphoric acid (concentrated) CAS# 7664-38-2	DOT: Class 8 Corrosive NFPA: H3, F0, R0	**Undiluted**: Contact approved disposal facility for disposal **Diluted**: Small amounts dilute to <1%, neutralize, flush with copious amount of water to sewer

(*continued*)

TABLE 2.4. (*Continued*)

Laboratory chemical (Small Quantities)	DOT hazard classification NFPA rating[a]	Common disposal methods[b]
Sodium hydroxide CAS# 1310-73-2	DOT: Class 8 Corrosive NFPA: H3, F0, R1, S-CORR	**Undiluted**: Contact approved disposal facility for disposal **Diluted**: Small amounts neutralize, dilute to <1%, neutralize, flush with copious amount of water to sewer
Sodium thiosulfate CAS#10102-17-7	DOT: Not regulated NFPA: H1, F0, R0	**Undiluted**: Neutralize, dilute to <1% **Diluted**: Dilute to <1%, flush with copious amount of water to sewer
Sulfur dioxide CAS# 7782-99-2	DOT: Class 2.3 Poison Gas NFPA: H3, F0, R0 S-CORR	**Dry**: Contact approved disposal facility for incineration, oxidize to inert sulfate salt **Gas**: Bleed gas into water mixture of 15% NaOH to neutralize, flush with copious amount of water to sewer
Sulfuric acid (concentrated) CAS# 7664-93-9	DOT: Class 8 Corrosive NFPA: H3, F0, R2 S-~~W~~	**Undiluted**: Contact approved disposal facility for disposal **Diluted**: Small quantities dilute to <1%, neutralize, flush with copious amount of water to sewer
Tartaric acid CAS# 133-37-9	DOT: Not regulated NFPA: H2, F1, R0	**Undiluted**: Contact approved disposal facility for incineration **Diluted**: Small quantities dilute to <1%, flush with copious amount of water to sewer
Triethanolamine CAS# 102-71-6	DOT: Not regulated NFPA: H2, F1, R1	**Undiluted**: Contact approved disposal facility for incineration **Diluted**: Small quantities dilute to <1%, flush with copious amount of water to sewer

[a] H=health; F=fire; R=reactivity; S=specific hazard.

[b] Contact federal, state, and local authorities for disposal guidelines in your area to assure compliance.

2.4.5 Personal Protection Equipment

Knowledge of chemicals is the primary tool for successful personal protection. Proper personal protection equipment (PPE) and chemical protective clothing (CPC) for every type of possible chemical exposure in each individual laboratory must offer the maximum level of protection. The amount of protection required will depend on the degree of chemical toxicity, exposure scenario, and risk potential. OSHA requires PPE and CPC be provided to each employee and the equipment be used and maintained in clean and reliable condition. PPE includes eye, ear, face, head, and extremities protective clothing, respiratory devices, and adequate barriers. Each laboratory should have its own PPE and CPC equipment stored in that laboratory. Consult OSHA 29CFR 1910.133 for details.

For routine working conditions where there is no handling of severely toxic chemicals, the following PPE should be worn:

- A cotton laboratory coat to provide first-line defense protection against chemical splashes, vapor, and particulate matter. Laboratory coats should be free of holes, tears, and frayed edges. The coat should fit well and allow free movement. Sleeve length should cover the arm to the wrist. Rolling sleeves to the wrist creates bulk that could get entangled or caught on equipment. Laboratory coats should not be worn outside the laboratory.
- Splash-proof safety glasses with side shields to provide protection to the eyes. To date, OSHA does not require safety glasses but strongly recommends their use. OSHA does require laboratory staff that wear corrective lenses be supplied with prescription safety glasses or safety goggles that fit over nonsafety glasses.
- Disposable gloves to protect hands and forearms from splashes.
- Shoes that cover the entire foot and have nonslip soles.

What not to wear under laboratory coats are shorts, midriff tops, tube tops, halter tops, cropped pants, open-toed shoes, or sandals. Keep your skin covered and protected. Long hair should be pulled back to prevent obstruction of vision, dipping into chemicals, catching fire, and entanglement. Dangling jewelry should be removed to avoid entanglement in glassware or equipment and dipping into chemicals. Torn or ragged clothing and clothing that is too large should be avoided to prevent entanglement, dipping into chemicals, and hindering mobility.

Before handling severely toxic chemicals, read the MSDS for the manufacturer's suggestions on the proper PPE to wear. Health and safety professionals can provide additional guidelines. Added PPE might include the following:

- Disposable chemical-resistant sleeves
- Splash-proof safety glasses with side shields or goggles
- Face shield
- Chemical-resistant apron
- Chemical-resistant gloves
- Dust mask or respirator
- Chemical resistant pants or coveralls

Figure 2.3 illustrates proper PPE when working with hazardous and volatile chemicals.

FIGURE 2.3. Example of personal protection equipment.

2.4.6 Chemical Accidents and Emergencies

Working in a hazardous environment dictates that all laboratory staff must be trained to handle chemical spills, accidents, and emergencies. Knowing the procedures for potential problems will make responding to accidents or emergencies faster and more effective. Quick response time and appropriate action can save lives and control damage.

2.4.6.1 Spills

When an accidental spill occurs, immediately notify laboratory personnel in the area; if alone, contact any person in the area, and let them know what has happened. Evacuation might be necessary.

Help any injured person first and notify the emergency contact in your facility for assistance. For persons who have been injured or contaminated with small amounts of chemical, use the following procedures:

Immediately flush contact area with water for no less than 15 min. If the eyes are the contact point, get to an eyewash station, hold the eyelids open and flush with potable water, remove contact lenses quickly, and seek medical attention.

For contamination of the face, hands, and arms, use the sink faucet to flush the site; remove jewelry and contaminated clothing while continuing to flush the site. When there are larger areas of contact with skin and clothing, use the safety shower. Quickly remove all contaminated clothing, shoes, and jewelry while in the safety shower (see Fig. 2.4). DO NOT BE MODEST; every second counts. Be very careful in removing clothing to avoid additional skin contact or spreading the chemical into the eyes. Clothing might best be removed by cutting it off rather than pulling the clothing over an injured person's head.

After flushing, check the contact site. If there is no visible burn, wash the area with soap and water. Seek medical attention for the slightest burn. Do not put anything on the site—no creams, lotions, or salves. Take a copy of the MSDS to the hospital or physician's office to assist the medical staff in treat-

FIGURE 2.4. Eyewash and shower station.

ing the injured person quickly. Exposure to certain chemicals can lead to other physical problems and the doctor and patient will benefit from the MSDS information.

Attempt to contain the spill and avoid putting anyone in jeopardy. Locate the MSDS information as soon as possible and determine the best absorbing material to contain the spill. Use absorbent spill pillows for liquid chemicals such as acids, bases, and solvents. Other absorbents such as clay, sand, vermiculite, kitty litter (for nonoxidizing substances) or the use of a specific spill kit containing the proper material can be used. The MSDS most often contain a list of neutralizing agents that can be applied to a spill or excess chemicals. Sodium bicarbonate is often used to neutralize acids and sodium bisulfate to neutralize bases. Spill pillows, absorbing materials, and, in some cases, neutralized waste are considered solid waste and require proper handling and disposal. Consult the MSDS for disposal instructions.

Turn off hot plates, stirrers, and equipment in the area that could possible ignite the chemical. Set up appropriate warning signs in clear view to protect other personnel. Clean the spill using the appropriate PPE and procedures. Do not attempt to clean a significant spill alone. Use situation-specific tools to clean up the waste and place the waste in a proper receptacle. Wash the area two to three times with a sponge or cloth and a mild detergent and water and then dry with rags or paper towels. Wipe down all containers or equipment that might have been contaminated with rags or paper towels. Place sponges, cloths, rags, and paper towels in the appropriate receptacle. Hazardous material cleanup requires extreme care and all cleaned up materials, tools, cloths, rags, and paper towels must be handled as hazardous waste.

Mercury spills should be isolated before collecting the droplets (wearing the appropriate PPE, of course). Large droplets can be consolidated into a pool using a scraper or piece of cardboard and removed via a pump or similar equipment in the case of large spills. Do not use a regular vacuum cleaner. For smaller spills, use a wet paper towel or a piece of adhesive tape to pick up the droplets. It is prudent to keep a mercury spill cleanup kit at the ready. These kits contain instructions and the supplies to handle a small-scale spill. All waste should be placed in a high-density polyethylene container and sent to an approved reclamation center. The spill area will require decontamination by using a mercury decontamination kit.

2.4.6.2 Accidental Inhalation or Ingestion

Inhalation of a chemical can lead to delayed symptoms. The victim should leave the area immediately and be encouraged to take deep breaths of fresh air. If the inhaled chemical is not an irritant, corrosive, or very toxic, contact a physician if symptoms such as coughing or shortness of breath occur. If the substance inhaled is an irritant, corrosive, or toxin, contact a physician immediately. Do not wait for symptoms to develop. Transport the victim to a hospital.

Chemicals that pose an inhalation hazard or reactions that can generate inhalation hazards should only be worked with and conducted inside an exhaust fume hood. The fume hood should be vented to the outdoors with the appropriate scrubbers/traps installed. The doors of the hood should be closed as much as possible while working and completely closed when not in use. The fume hood should achieve an air velocity at the face of the unit of 100 ± 20 feet per minute at the opening to assure adequate airflow. Chemicals should never be stored in a fume hood.

In the event of ingestion of an irritant, corrosive, or volatile substance, do not induce vomiting. Have the victim drink one or two glasses of water to dilute the chemical. Very toxic chemicals might require the victim to drink activated charcoal slurry to absorb the chemical. Contact the hospital or poison control center immediately.

When a victim has ingested a highly toxic substance call the hospital or poison control center immediately. If the substance has a fatal dose to humans of 1 teaspoon or less, it might be wise to take the risk and induce vomiting by giving the victim salt water or Ipecac syrup.

Nonirritant, corrosive, or volatile substances that have a low toxicity require dilution of the chemical. Have the victim drink several glasses of water and call the hospital or poison control.

Concentrated acid ingestion needs immediate dilution to prevent severe tissue damage. Because the water addition will react with the acid and create heat, give the victim several glasses of very cold water and call the hospital or poison control center immediately. With ingestion of a dilute acid, give the victim cold water and an antacid such as Maalox® or Milk of Magnesia® to neutralize the acid and then call the hospital or poison control center.

If the victim has ingested a concentrated or dilute base, give them cold water to dilute the substance and immediately call the hospital or poison control center.

2.4.6.3 Fire

The use of flammable chemicals such as ethanol, denatured alcohol, hydrogen gas, acetic acid, and acetone is a daily event in the wine laboratory. Denatured alcohol burners are used in a variety of assays; ethanol is used in chemical standards and for sanitizing in the lab, cellar, and bottling lines. Hydrogen is used as a carrier gas for gas spectrometry. Ignition sources such as stirring plates, equipment motors, and static are everywhere and great care must be taken to avoid the chance of a fire.

Proper training in the use and the appropriate choice of fire extinguishers is imperative, and it is the responsibility of the laboratory worker to know the location, operation, and limitations of the fire extinguishers in the work area.

There are four classes of fires and specific fire extinguishers for each class (NFPA):

- Class A: Ordinary combustible materials such as wood, paper, cloth, some plastics, and rubber can be extinguished using either water or a dry-chemical extinguisher.
- Class B: Flammable liquids, oils, greases, tars, oil-based paints, lacquers, and flammable gases can be extinguished using a carbon dioxide or dry-chemical extinguisher.
- Class C: Electrical fire energized by electrical equipment can be extinguished using a carbon dioxide or dry-chemical extinguisher.
- Class D: Combustible metals such as titanium, sodium, magnesium, and potassium can be extinguished using a Met-L-X® extinguisher.

Carbon dioxide extinguishers are recommended for fires involving computer equipment, delicate instruments, and optical systems because the carbon dioxide will not damage the equipment. It is recommended that laboratories be equipped with carbon dioxide and dry-chemical fire extinguishers.

Fires in small containers can most often be extinguished by simply covering the container and suffocating the fire. Containers of burning materials should never be picked up and moved to a sink or outdoors. Small fires can be put out with the appropriate extinguisher. Do not attempt to put out a fire with an extinguisher unless trained and confident in its use. The situation can be worsened by spreading or blowing flammable material to other sections using pressurized extinguishers.

For more serious fires, evacuate the laboratory and activate the nearest fire alarm. Do not attempt to put out the fire. If possible, shut off the gas lines and take the chemical inventory list with you as you leave the site. Be prepared to inform the fire department of the hazardous substances in the laboratory as well as the location of compressed gas cylinders.

In the event that a person's clothing catches fire, have them drop to the floor and roll until the flames are extinguished, or if the safety shower is close, use it to extinguish the fire. Do not let them run or try to beat the flames. Quickly relocate the victim to a safe location, remove the affected clothing immediately, and douse the victim with water. Apply clean, wet, cold cloths on the burned areas until medical help arrives.

2.4.6.4 Gas Cylinder Leaks

Check the cylinder valve and make sure that it is closed. A suspected leak in a cylinder can be confirmed by applying soapy water or a 50% glycerin–water mixture to the suspicious area and looking for bubbles. Laboratory staff should never try to force a leaking valve closed. If the leak at the cylinder valve cannot be closed, reinstall the packing nut or valve gland and notify the gas cylinder provider. If the leak continues, immediately contact the appropriate gas cylinder provider to assist with the problem. Gas cylinders that develop leaks should be removed from the laboratory to a well-ventilated area using the appropriate PPE and transport equipment.

Warnings should be posted to keep the area clear and describe the type of hazard.

Flammable, inert, or oxidizing gas in cylinders should be handled with great care to prevent ignition. A leak in a cylinder of corrosive gas might increase in size as the gas releases, requiring immediate relocation. Toxic gases should be removed from the laboratory immediately by personnel properly protected including self-contained breathing apparatus.

For minor leaks of corrosive or toxic gas cylinders evacuate the area; place a plastic bag over the top of the cylinder, tape it shut, and then transport it to a safe area. Larger leaks might require evacuation of laboratory staff and EPA notification. Handling larger leaks in corrosive or toxic gas cylinders will require proper PPE including self-contained breathing apparatus.

After isolation, toxic and corrosive gas cylinders can be equipped with gas lines incorporating antisiphon valves or traps. The gas is then bubbled through an appropriate neutralizing liquid.

2.5 Physical Hazards

The physical hazards we face in the wine laboratory, cellar, and bottling lines are numerous (Table 2.1). Wine laboratory responsibilities require staff members to traverse into the grape crushing areas, the cellar, bottling line, tasting rooms, receiving, and shipping. We obtain samples, monitor fermentations, inspect bottles, fix equipment, perform analyses, monitor quality, move cases of wine, clean glassware, pick up supplies, ship packages, prepare paperwork, put in computer time, change compressed gas cylinders, and so much more that the risk of an accident or injury can be high if unprepared.

2.5.1 Physical Hazards Associated with Laboratory Work

Common hazards found in most wine laboratories involve equipment, vacuum systems, glassware, cryogenic material, compressed gas cylinders, ergonomics, and the general working environment. Know the risks associated with daily laboratory function, as it is often these small daily events that create the greatest hazards for laboratory staff. The adage "better to be safe than sorry" certainly applies here.

2.5.1.1 Equipment Hazards

It is always prudent to read the instruction manuals for all equipment *before* you begin using a piece of equipment. Keeping equipment in good working order and performing the recommended scheduled maintenance not only keeps the equipment safe but prolongs the life of the equipment. Laboratory equipment is expensive and, for some companies, difficult to justify, so keep it in the best working condition. Working with laboratory equipment poses several risk factors:

- Shock
- Electrocution
- Spark generation
- Fire
- Punctures
- Burns
- Eye damage
- Explosions
- Cuts
- Entanglement

Electrocution, shock, and accidental ignition of flammables can be prevented by using common sense and simple safety rules and practices:

- Use nonsparking induction motors without variable autotransformers in flammable environments.
- Inspect and replace any frayed or damaged cords; check cords monthly.
- Use electrically insulated equipment only.
- Do not use household appliances with series-wound motors in flammable areas.
- Ground all equipment and use with ground-fault circuit interrupter (GFCI).
- Place equipment in a safe location away from spills, flammable vapors, or condensation unless the equipment is designed for that purpose.
- Unplug equipment prior to any repair or maintenance.
- Use only equipment that meets the NFPA National Electrical Code.
- Equip or use equipment with thermal shutoffs.
- Do not attempt repair on equipment unless you are qualified.
- Know the location of all power main switches and circuit breakers in the area.
- Keep work areas clear and clean spills immediately.
- Dust equipment regularly.
- Use caution when working with moving parts.

Heating devices such as hot plates, heating mantles, aquarium heaters, distillation stills, heat baths, and autoclaves should be equipped with variable autotransformers to control the heating level and with temperature-sensing devices to shut off power in the event of overheating, which can cause fires, explosions, and destruction of equipment.

Cooling systems for condensers such as water recirculation units or water flowing from a tap can create unsafe flooding conditions in a short time. Inspect all connections on a regular basis and replace any connection or tubing showing signs of wear. Use proper hose clips and secure the drain tube to the sink or drain to prevent the tube from moving. Quick connects with check valves should be used as much as possible, but if cost is a factor, plastic locking disconnects can be used.

Centrifuges should be equipped with shut-off switches that turn off the power when the lid is raised. Keep your hand out of a moving centrifuge, as serious injury can occur. Balance the sample load in a centrifuge to prevent spilling and ensure smooth operation.

Specialized instrumentation that requires the use of hydrogen or other flammable gases should be well grounded and placed in a room that has static-free grounded flooring or grounded floor mats to prevent any static electric spark.

2.5.1.2 Compressed and Liquid Gas Hazards

Compressed gas cylinders used in the laboratory require extreme caution. First and foremost, any container of gas under pressure should be regarded as a ballistic missile.

Due to the danger of compressed gases, it is wise to order the smallest volume needed to avoid unwanted larger cylinders. The larger the cylinder, the more hazards, and it is not only the cylinder itself but also the handling, storage, and movement of the cylinder that creates additional hazards. Storage, movement, and leak control of cylinders have been addressed earlier in the chapter (see Sections 2.4.3.1, 2.4.3.3, and 2.4.6.4).

Cylinder valve connections are standardized by the Compressed Gas Association (CGA) to prevent mixing of incompatible gases. Cylinder valve connections are straight threaded nipples and are specific to a type of gas. The connection threads will vary in diameter, be right or left handed, and might be inside or outside threads (female/male). The seal is formed by a metal-to-metal interface, eliminating the use of Teflon tape, which can weaken the connection. Only CGA standard combinations of valves and fitting should be used. Adapters should never be used and do not cross-thread a fitting.

A compressed gas cylinder should be equipped with a pressure-compensated regulator that will break down, or reduce, the higher pressure to a manageable working pressure. This break down of pressure is called a stage. Most often for laboratory use, a "double-stage" regulator is used, but the number of stages will depend on the degree of gas control required for the job. A pressure-compensated regulator has more accurate gauge pressure readings because the line pressure does not affect the reading. Unlike other gauges, a higher line pressure can show a lower pressure reading because of back-pressure buildup in the regulator valve. Corrosive gases require regulators made with corrosion-resistant materials and carbon dioxide requires a specially designed regulator.

Cylinders and regulators must be equipped with pressure-relief systems to avoid excess pressure buildup, resulting in the weakening of the cylinder lead-ing to possible explosion. The majority of regulators manufactured today have built-in pressure-relief valves. It is always helpful to know the pressure-relief limit, or pop-off, of the regulator used. Cylinders are never filled to maximum capacity allowing for gas expansion and increased pressure.

Never use a screwdriver or pliers when removing caps and opening valves. Metal to metal can create sparks. When cleaning connections or attaching regulators, never use oil or grease that could react with some gases, (e.g., oxygen). Depending on the gas, it is wise to crack the tank valve slightly, letting out a small burst of gas. This will blow out any debris at the connection that might damage the regulator.

Liquefied gases such as liquid nitrogen are used in the wine laboratory as a coolant in certain assays. Hazards associated with liquid gases include frostbite, degradation of structural materials, asphyxiation, fire, and explosion. In addition, use of a liquid gas cylinder in the laboratory generates an icy buildup along the supply lines that will melt and create a slip hazard. Insulation of the pipes leaving the cylinder can help reduce the amount of water condensation.

Containers for the small volumes of liquid gases that are commonly used in the laboratory are called Dewar flasks. Cylinders built for liquid gases in volumes of 100 to 200 liters are especially built for high pressure, are insulated, and have multiple built-in pressure-relief valves.

Liquid gas cylinders should not be filled to more than 80% of their capacity to allow for thermal expansion. These cylinders should be located in a well-ventilated room to prevent the chance of oxygen displacement by the vaporized gas.

Personnel handling a cylinder exchange should wear appropriate PPE that includes dry gloves and a face shield. First-time users should ask for training from the liquid gas supplier or an experienced co-worker.

2.5.1.3 Vacuum Hazards

Laboratory vacuum systems or vacuum pumps are used on a daily basis in the wine laboratory to evacuate gases from samples or to aid in filtration of substances. Implosion, flying glass, and chemical spattering are the most common hazards associated with vacuum use.

Glass vessels should be inspected for any sign of weakness (star cracks, scratches, and etching marks) before use. Never use a glass vessel for high-vacuum work; glass is used only in low-vacuum operations. Do not evacuate repaired glassware, thin-walled flasks, or Erlenmeyer flasks larger than 1 liter; they just will not stand up to the negative pressure.

Vacuum systems should be outfitted with the proper traps and exhaust. Check with the pump manufacturer for guidelines on the proper care of the system and the types of substance that is or is not allowed in the pumping system. Common building vacuum systems that are used by several departments can create hazards if the wrong chemicals or gases are aspirated and mixed.

2.5.1.4 Glassware Hazards

Cuts, cuts, and more cuts! Inspect the glassware for chips and cracks daily and before using it in any type of assay. Glassware that is chipped or cracked should be discarded into a proper glass waste container or set aside for repair.

Wine bottles used for samples should be inspected daily as well. Chipped or cracked bottles should be discarded into glass-recycling bins. Use a carrier to transport sample bottles to the laboratory. Sample bottles with fermenting juice can explode if they are capped tightly. Always leave juice sample bottles loosely capped.

Secure glassware in dishwashers to prevent damage. Drawers and cabinets can be lined with nonslip materials to protect glassware from moving and possible damage. Never carry glassware in wet or soapy hands. Use two hands when transporting larger pieces of glassware to prevent dropping.

Replacing polished rounded-edge glass tubes in stoppers or corks requires extreme caution. It might be prudent to assess the cost–risk factor when replacing these glass tubes. It can be less expensive to buy new tube/stopper setups than risking injury. If replacing the tubes, use the proper PPE with the addition of a towel or rubber barrier around the glass tube in case it breaks. The tubes should be lubricated well before inserting them into the stoppers.

Use the proper PPE when opening glass vials. Snapping off the tops can send glass flying or the vials can break in your hands.

Leaving a distillation still's heating elements on and unattended during use can lead to evaporation of water in the boiling chamber and expose the heating element. This will result in overheating of the glass. The hot glass can render severe burns and can explode, showering the area with glass (see Fig. 2.5). Never leave a distillation still unattended. Never add cold water to a hot dry still, and always turn the heating element off and let the glass cool.

2.5.1.5 Slip, Trip, and Fall Hazards

Accidents due to slips, trips, and falls are high on the accident lists of most laboratories. One of the main causes of these types of accident is bad housekeeping. Floor spills must be cleaned immediately, be they chemical or plain water. Wet floors during rainy or snowy weather can create a big hazard and putting down nonskid door mats is a simple solution. Placement of nonskid floor mats in potentially slippery areas such as in front of the dishwashers, sinks, wet chemistry areas, and liquid gas tank storage areas can eliminate the chance of slipping.

Electrical cords, boxes on the floors and in stairwells, uneven floors, stairs, and computer connections are examples of trip hazards that could result in a fall.

FIGURE 2.5. Boiling still.

2.5.1.6 Ergonomic Hazards

All employees should be trained in the proper ergonomic practices for their particular work area. Injuries to joints, ligaments, muscles, tendons, spine, cumulative trauma disorders, and eye strain are on the increase in the workplace. The National Institute for Occupational Safety and Health (NIOSH) guide U.S. DHHS, 1994, should be consulted for more information.

Starting the day out with a good stretch and taking stretching breaks throughout the day can be helpful to keep muscles loose and promote good circulation. Most people are prone to strains and pulls after they eat because the blood tends to migrate from the muscles to the internal organs. Stretching after a meal will get the blood stirring and back into the musculature. To keep alert, blood circulating, and help prevent injury, take all assigned breaks. Take the time to put your feet up and relax or take a slow relaxing walk.

Ergonomic hazards include the following:

- Sitting for long periods
- Standing for long periods
- Lifting
- Carrying
- Pushing/pulling
- Repetitive motion

Long periods of sitting are most often associated with computer work. It is recommended to use a chair with a backrest that provides constant support of your lower back curve and allows sitting deep in the seat without pinching or rubbing the lower thighs. Sit 18–24 in. away from the computer monitor, with the screen just below eye level. Sit the keyboard on a flat surface or angled down just below elbow level and at a distance that will let the elbows remain at the side. Hands should be in a neutral and relaxed position with no bend. Do not remain in the same position of long periods of time. Get up, walk around, or stretch frequently.

Many laboratory workers stand for long periods of time performing analysis. It is important to have good supportive shoes and well-placed stress-reducing nonskid floor mats. A footrest can be used to vary stance during the day. Try not to slump, and keep the shoulders erect to prevent strain on the upper back. Tilting the pelvis will help to relieve lower back strain, and knee strain can be reduced by keeping the knees flexed slightly. Sit when you can and stretch occasionally.

Repetitive strain injuries occur from continuous physical stress over a long period of time. Computer work, manual pipette work, turning stopcocks, and so forth can create damage of the nerves, ligaments, and tendons of the wrist. Try to keep wrists in a neutral and relaxed position. Frequent shaking and rubbing of the hands and wrists helps increase circulation. When performing a twisting motion, stretch the opposing muscles occasionally. Opening and closing the hand into a fist will help relax it and increase blood supply.

Lifting is the major cause of back strains in a laboratory. Laboratory staff will move boxes of supplies, boxes of wine samples, 5-gal water containers, and equipment. Proper lifting techniques help reduce strains and back injuries. Lifting should always be done from a stable position, leverage advantage, and functional comfort. Straddle the object, maintain spinal curves, lift with the legs, never twist the body, and smoothly rise up into a standing position.

Never reach around and pick up an object when the body is twisted. To pull or push an object, stabilize the elbows against the legs, shift the body weight using the legs, maintain spinal curves, and do not overextend or reach.

2.5.2 Physical Hazards in the Cellar

Most of the safety precautions discussed in Section 2.5.1 applies here, but there are a few hazards indigenous to the cellar that necessitates mentioning.

The winery cellar is wet most of the time from constant wine movements and cleaning. The use of electrical pumps, stirrers, and filtration equipment pose a grave danger for electrocution and great care must be taken to ensure that the equipment is well grounded and in perfect working condition. Slips are very common in this wet environment, so wear shoes with good traction, maintain good housekeeping, and post hazard signs to warn others.

The cellar contains tanks that hold wine and they can vary in capacity from a few hundred gallons to 100,000 gallons or more. Drowning is a very real danger when working around these tanks. Untrained personnel should never be allowed to obtain samples from the tops of tanks. Never lean into a tank or stick your head in a tank.

Hoses used in the winery cellar are large, high pressure, rugged, and very heavy. Strains, pulls, and back injuries are very common. Large hoses should never be moved by a single person; always ask for help. The hoses are everywhere and create a trip hazard at every step. Winery cellar personnel should be diligent in keeping unused hoses put away in hose beds and alleviate as much hose congestion as possible.

A full tank of wine puts a great deal of pressure on hose connections. If a hose is not connected properly or the hardware is weakened, it is not uncommon for hoses to blow off tanks. This serious danger could cause severe injury or death. Double-check the hose connections before the valve is opened. Leaking connections should be reported to the cellar staff immediately. Leaks can be a sign of failure.

Because of the tremendous pressure of a full tank, care should be taken when opening a tank valve for any reason. If a valve is opened too fast, wine can gush out at a tremendous velocity, knocking a person to the ground. Go slow, crack the valve open, and then open it very slowly.

Tanks are usually filled with an inert gas after cleaning to keep the tank sanitary. *Never* enter an empty tank without the proper training and breathing equipment and *never* enter it alone. A person can be rendered unconsciousness after just a few breaths. Sadly, the majority of deaths in wineries are the result of asphyxiation caused by the worker entering a gassed tank.

Around the tops of large tanks there are normally stainless-steel walkways called "catwalks" that allow workers to access the tops of the tanks. These catwalks and the stairs that lead to them can become very slippery. Attention must be paid to where a person steps and both hands should be kept on the handrails at all times. Figure 2.6 shows a typical work area, tanks, catwalks, and forklift traffic.

Wooden barrels in the cellar normally have a capacity of 55 gal and create their own hazards, such as crushing, splinters, cuts, abrasions, muscle strains, and back injury. Wear adequate PPE to prevent splinter, cuts, and abrasions. *Never* attempt to move a full or partially full barrel. Barrels should only be moved on a barrel rack using a forklift. Never climb barrels or stacked barrel racks to obtain samples. Contact a cellar employee with a forklift for assistance.

Forklifts are in constant motion in a cellar—moving barrels, pallets of materials, and cases of wine. When laboratory staff members are working in areas of low visibility, such as in the midst of stacks of barrels, wearing a bright safety vest is advised. It is difficult for forklift drivers to see the workers among the barrels. Barrels can be stacked on racks several barrels high and close together in long rows (see Fig. 2.7). The vest will alert the drivers to the worker's presence. In addition, some wineries require that brightly colored flags be place outside the row of stacked barrels to alert the forklift drivers that someone is working in that row of barrels.

During fermentation of the grape juice carbon dioxide is produced as a by-product from the conversion of sugar to alcohol. Working in the cellar at this time of the year requires extreme caution and implementation of procedures

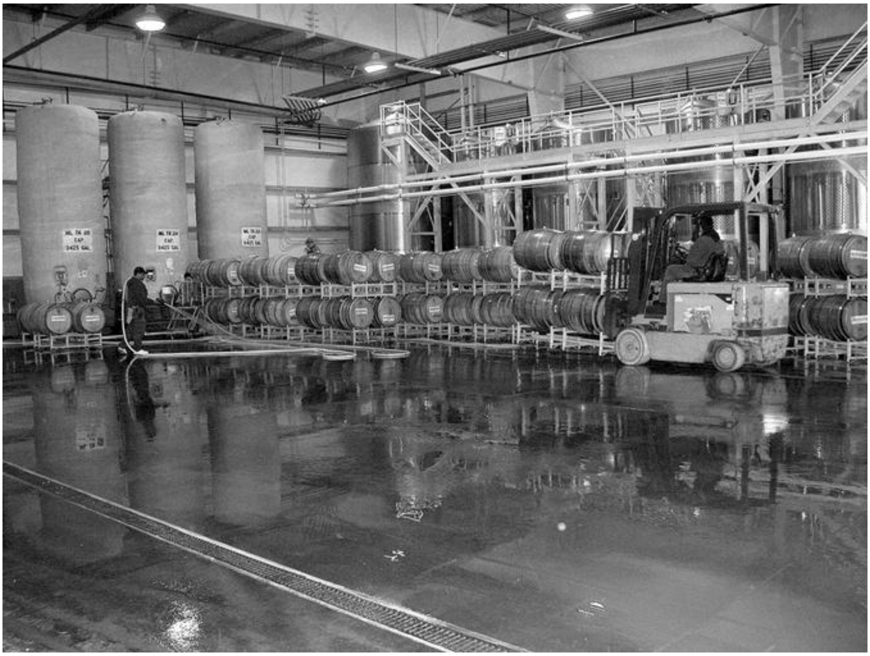

FIGURE 2.6. Work floor, tanks, and catwalks.

FIGURE 2.7. Stacked barrels in cellar.

to prevent the buildup of carbon dioxide in the cellar areas. Most modern-day wineries have air-exchange units installed that will cycle on when the carbon dioxide reaches a certain level, exhausting the heavier carbon dioxide-laden air near the floor while bringing in fresh outside air. Older wineries keep their doors open and use fans to circulate the air. Regardless of the method, it is prudent to manually check the carbon dioxide levels with a meter several times a day. Staff working amid fermenting juices might require carbon dioxide-metering alarms that will allow them to exit the area if the carbon dioxide level begins to rise. Taking frequent breaks and getting some fresh air is a wise practice to incorporate during this period.

Equipment used to bottle wine is large, noisy, and dangerous. PPE must be worn at all times and should include proper eye protection, proper clothing, and hearing protection.

Bottles smashing to the floor as they fall off the moving conveyor belts, bottle tops shattering as the corker jaws (used to hold the bottles in place while the cork is inserted) lose their adjustment, and bottles exploding from a misaligned filler nipple are all elements of the cacophony of bottling. A noise conservation program is required by OSHA if the noise level exceeds the 8-h time-weight average of 85 decibels. Hearing protection in the form of earplugs or earmuffs is required in areas where the noise levels exceed 90 dB. Comprehensive monitoring, personnel training, and hearing tests for employees must be carried out by a facility. Eye protection is mandatory in this area.

Entanglement is a very real hazard when working around the bottling equipment. There are many moving parts that can catch hair, hair nets, hands, sleeves, and jewelry. Use extreme caution and adhere to safety policies and procedure for emergency shut-off. Shut down equipment prior to repair or maintenance.

The floors are usually wet and in some areas very slippery due to lubricant used on the conveyor belts. Wear shoes with good traction, maintain good housekeeping, and post hazard signs to warn others.

2.5.3 Damage Control

The professional laboratory worker follows a few commonsense rules to ensure everyone's safety. Table 2.5 lists the laboratory safety "rules" that most laboratories follow. Every laboratory should create its own set of rules and guidelines depending on the type of work performed in that laboratory and the current company policies.

TABLE 2.5. List of safety rules for laboratory professionals.

- Do not startle or distract other workers.
- Do not allow practical jokes or horseplay.
- Do not prepare food, eat, or drink in areas using chemicals.
- Do not smoke.
- Do not apply makeup or take medication in areas using chemicals.
- Do not use laboratory refrigerators for food storage.
- Do not taste or smell chemicals.
- Do not siphon or pipette by mouth.
- Do not use the telephone while performing analysis.
- Do not store chemical containers on the floor.
- Do not obstruct access to exits and emergency equipment.
- Do not use stairways or hallways as storage areas.
- Do not leave a chemical reaction unattended.
- Do not work with chemicals when alone.
- Do not run with chemicals or glassware.

TABLE 2.5. List of safety rules for laboratory professionals. (*Continued*)

- Do not wear laboratory coat and gloves to the restroom.
- Always be familiar with the chemicals you are using.
- Always wash your hands thoroughly after using chemicals, gloves or no gloves.
- Always clean spills immediately.
- Always carry glass containers using two hands.
- Always secure gas cylinders.
- Always use an exhaust fume hood when working with inhalation hazards.
- Always properly store chemicals.
- Always keep your work area clean and neat.
- Always label every beaker, flask, or container containing any substance, even if it is temporary.
- Always unplug equipment before repairing.
- Always remove your laboratory coat and gloves when leaving the laboratory.
- Always wear appropriate personal protection equipment.

It is the responsibility and requirement of the employee to understand and act in accordance with the safety requirements established by the laboratory and facility, wear and properly maintain PPE, follow good chemical hygiene practices, participate in all required training programs, read and understand health and safety standard operating procedures, divulge all facts pertaining to accidents, and provide required information to examining physicians.

Hey, be safe out there.