CHAPTER 2

Safety in the Clinical Microbiology Laboratory

CHAPTER OUTLINE

Laboratory Safety
Exposure Control
Fire Safety
Chemical Safety

KEY TERMS

Biohazard
Biosafety Level
Disinfection
Standard precautions
Sterilization
Universal precautions

LEARNING OBJECTIVES

1. Describe the elements of a laboratory safety program as applicable to the student microbiology laboratory.
2. List and describe the possible routes of laboratory-acquired infections.
3. Name the agencies that recommend policy for laboratory safety.
4. Discuss the concepts of standard precautions and universal precautions.
5. Describe and practice the general guidelines for safety in the clinical laboratory:
   a. Discuss personal protective equipment and its purpose in the clinical laboratory.
   b. Describe safety precautions with specific applications to the microbiology laboratory.
6. Summarize the criteria for and differentiate Biosafety Levels 1, 2, 3, and 4.
7. Describe and differentiate the various types of biological safety cabinets.
8. Define and give examples of sterilizers, disinfectants, and antiseptics.
9. State the principle of the autoclave.
10. List and define the five types of hazardous chemicals.

Laboratory Safety

In addition to safety risks associated with any clinical laboratory, such as chemical, fire, electrical, and radioactive hazards, the microbiology laboratory presents the hazard of exposure to infectious agents, or biohazards. Biohazards are biological substances that may present a health risk to humans. Clinical specimens are potential biohazards to laboratory personnel because the specimens may contain human immunodeficiency virus (HIV); hepatitis B virus (HBV); and numerous other bacterial, viral, and fungal agents.

Possible routes of infection that may occur in the microbiology laboratory include airborne, ingestion, direct inoculation, mucous membrane contact, and arthropod vectors. Each of these routes is summarized in BOX 2-1.

Guidelines to ensure safety in the clinical laboratory have been compiled by several agencies, including the Occupational Safety and Health Administration (OSHA), the Centers for Disease Control and Prevention (CDC), the College of American Pathology (CAP), and the Joint Commission (JC). Of particular significance is the publication of standards for bloodborne pathogens by OSHA, which were published in the *Federal Registry* in 1991. Standards for bloodborne pathogens are updated periodically by OSHA. The recommendations of these agencies can be used to develop safety regulations for the student microbiology laboratory.

Exposure Control

Each facility is required by law to have a laboratory safety officer and an exposure control plan. The safety officer oversees the development and implementation of a safety program, orientation of laboratory employees, preparation of a laboratory safety manual, and the development and implementation of the exposure plan. In the education setting, this officer may be a faculty member or an individual designated by the institution to oversee the general safety and well-being of employees and students. The **exposure control plan** describes the risk of exposure to infectious agents for all job classifications and explains exposure-reduction methods. The exposure plan must include procedures and documentation related to the following:

- Safety education
- Universal precautions and standard precautions
- Engineering controls
- Personal protective equipment
- Disposal of hazardous waste
- Postexposure procedures

SAFETY EDUCATION

Safety education includes orientation of new employees and continuing education for current employees regarding laboratory safety policies. In addition, current employees must receive continuing education regarding safety. All safety must be documented. Information may be compiled within a **safety manual**, which must contain policy and procedures concerning fire prevention and control, electrical safety, radiation safety, biohazard control, chemical hazards, hazardous waste disposal, and internal and external disaster preparedness. Safety policies should be posted or readily available to all individuals in the laboratory setting. The policy should be periodically reviewed and revised as needed. Employees who handle infectious

BOX 2-1 Possible Routes of Infection in the Microbiology Laboratory

Airborne: Aerosols may form during centrifugation of unstoppered tubes or from heating cultures or specimens too rapidly (sterilization of inoculating loops in the Bunsen burner flame), removing stoppers from tubes, or leakage from a container that holds contaminated specimens.

Ingestion: Infection may occur as a result of failure to wash hands or eating, drinking, smoking, applying cosmetics, or pipetting with the mouth.

Direct inoculation: Infection may result from needlesticks, broken glass, animal bites, or small scratches on the fingers.

Mucous membrane contact: Infection may occur if the organism can directly enter through the mucous membranes, such as through the conjunctiva of the eye.

Arthropod vectors: Infectious sources include ticks, fleas, and mosquitoes, which may harbor various microorganisms.

materials on a daily basis and those who have limited exposure, such as cleaning personnel, should be educated in the current safety recommendations of the facility.

UNIVERSAL PRECAUTIONS AND STANDARD PRECAUTIONS

Universal precautions are recommendations that describe the handling of clinical specimens by health care personnel, first introduced by the Centers for Disease Control (CDC) in 1987. According to the Clinical Laboratory and Standards Institute (CLSI), universal precautions are a set of preventive measures designed to reduce the risk of transferring HIV, hepatitis B virus, and other bloodborne pathogens in the health care setting. Universal precautions apply to all human blood and all other body fluids that contain visible blood (semen, vaginal secretions, and tissue and cerebrospinal, synovial, pleural, peritoneal, pericardial, and amniotic fluids). However, universal precautions do not apply to feces, nasal secretions, saliva except in the dental setting, sputum, sweat, tears, urine, and vomitus unless they contain visible blood. **Standard precautions** are a set of preventive measures, applied to all patients, that are designed to reduce the risk of infection in the health care setting. All blood, tissue, body fluids, secretions, and excretions (except sweat) are considered potentially infectious. A basic premise of standard precautions is that because the infectivity of any patient's blood and body fluids cannot be known, all patient blood and body fluid specimens must be treated as if they are potentially infectious.

All laboratory accidents, illnesses, and injuries must be reported immediately and recorded on the appropriate forms. Faculty, laboratory assistants, and students must complete the required incident reports in a timely fashion and follow the recommendations of the laboratory safety officer, including serological and clinical follow-up.

General guidelines to be followed in any clinical laboratory are summarized in BOX 2-2.

BOX 2-2 Safety Guidelines for the Clinical Laboratory

- **No food or drink** is permitted in the laboratory; no eating or drinking is permitted in the laboratory. Specimens may contain microorganisms that can induce infectious disease. No food or drink should be stored in clinical refrigerators. Separate refrigerators are required for food storage. These refrigerators should not be located in the clinical setting and should be labeled as to their contents.
- **No smoking** is permitted in the clinical laboratory. Smoking can ignite flammables and also may serve as a vehicle for exposure to microorganisms. Smoking is generally prohibited in most health care facilities.
- **Cosmetics**, including lip balm, are not to be applied in the laboratory because contamination is possible.
- **Protective eyewear** with side guards must be worn in all laboratories using hazardous chemicals or etiologic agents, in laboratories where animals are dissected, or if the threat of eye injury from flying debris may be a risk. The eyewear should be equipped with side shields. Regular prescription lenses are not suitable unless goggles are worn over the top of the prescription glasses. Contact lenses in those laboratories where volatile fumes are present are not recommended because the lenses may absorb the volatile fumes. Protective eyewear does not prevent this problem, and thus contact lens wearers should be advised to wear prescription glasses with protective eyewear over their glasses.
- **Face shields** with goggles and masks are recommended when working with agents that can infect through the skin or mucous membranes and when splashing may occur.
- **Clothing** should be clean and neat, and the use of **gowns**, **aprons**, or **laboratory coats** is required if splashing of blood or other body fluids onto the skin or clothing is likely to occur. Long-sleeved gowns with a closed front or long-sleeved laboratory coats that are buttoned are required. Disposable gowns, which can be autoclaved at the facility, are recommended. All protective clothing should be worn only in the laboratory or patient areas and is *not* to be worn in nonlaboratory areas. For example, laboratory gowns or coats must not be worn into the cafeteria or to the individual's home. Nondisposable gowns and coats must be properly **disinfected** and cleaned when contaminated, whereas disposable gowns and coats should be properly decontaminated and disposed of.
- **Shoes** should cover the entire foot; no open shoes, such as sandals, are permitted.

(*continues*)

BOX 2-2 Safety Guidelines for the Clinical Laboratory (Continued)

- **Hair** should be worn in a manner that prevents contact with contaminated materials as well as with moving instruments or equipment, such as centrifuges, in which it can become tangled. Those with **beards** must observe the same guidelines. **Jewelry** should not dangle, to prevent contamination or tangling into equipment.
- **Frequent and thorough hand washing** is required. The hands should be washed after removing gloves, before leaving the laboratory area, before and after patient contact, and before eating or smoking. The hands should be washed immediately after contact with blood or other contaminated specimens or materials. Care must be taken to scrub thoroughly, including areas beneath the fingernails.
- **Eyewash stations** must be located within 100 feet or 10 seconds of travel from any area in which hazardous chemicals (irritants, corrosives, acids, or toxic compounds) are used. The emergency eyewash must be plumbed into the fixtures; plastic wash bottles are not acceptable. The eyewash stations must be tested weekly to ensure proper working order and to flush out stagnant water.
- **Emergency showers** are required whenever corrosive or caustic chemicals are used. The shower should be tested periodically to ensure proper functioning.
- **Respirators** must be made available to those working in areas where the air may be contaminated with gases, fumes, vapors, or other harmful compounds.
- **Mouth pipetting** is strictly prohibited because of the possible ingestion of microorganisms and caustic chemicals. Pipette bulbs and automated devices are available for all pipetting needs.
- **Glassware** should be discarded in puncture-resistant containers when broken or chipped. **Sharp objects** should be handled with care. Needles should never be recapped, bent, or broken. All sharp objects must be placed immediately in puncture-resistant containers that are labeled as to the contents. Typical puncture-resistant containers for sharps disposal are illustrated in **FIGURE 2-1**. More information on sharp objects is found in the next section.
- **Centrifuges** must minimize the production of aerosols. Uncovered tubes or flammables should not be centrifuged; sealed tubes must be centrifuged at low speeds only. Sealed centrifuge tubes in covered cups or rotors are recommended for centrifugation of specimens containing microorganisms likely to become infectious through the production of aerosols.

FIGURE 2-1 Puncture-resistant sharps containers

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE) is a significant part of standard precautions; OSHA requires that employees must be protected from hazards encountered during work. In the laboratory, PPE includes protective laboratory clothing, disposable gloves, eye protection, and face masks. **Barrier protection** should be used to prevent skin and mucous membrane contamination with those specimens that adhere to universal precautions. **Gloves** should be worn when there is potential for skin contact with potentially infectious materials. Thus gloves should be worn when performing routine laboratory work and when handling materials contaminated with blood or other body fluids, such as instruments and specimen containers. Gloves also are recommended when performing phlebotomy and capillary puncture. Gloves should be changed between patients, and hands should be washed immediately after removing gloves. Gloves must fit properly, be replaced immediately if torn or contaminated, and not be washed and reused. Facial protection and a protective

body covering should be worn when splashes with blood or other fluids may occur.

High-efficiency particulate air (HEPA) respirators should be fit tested for each person; those who encounter mycobacteria through contact with either the patient or specimen should have access to a HEPA respirator. Laboratory employees who have contact with body fluids must be offered the hepatitis B vaccinations free of charge.

ENGINEERING CONTROLS

Engineering controls are needed to protect employees from the hazards that may occur during the performance of laboratory procedures. All laboratories must adhere to a minimum of **Biosafety Level 2 guidelines**. The CDC has classified microorganisms into various biosafety categories. These categories are based on several factors including number of occupational infections, infectious dose, and route of infection and are summarized in BOX 2-3.

Hazardous areas should be identified and labeled accordingly. The **biohazard** label (FIGURE 2-2) should be used to identify those areas of the laboratory where infectious specimens or cultures are stored or present. Needles, lancets, and other sharp objects should be placed immediately into puncture-resistant biohazard containers. Needles should not be recapped, bent, cut, broken, or removed from disposable syringes, to prevent an accidental needlestick.

FIGURE 2-2 Biohazard label

Air in the microbiology laboratory should move from areas of low risk to high risk and should not be recirculated after it passes through the microbiology laboratory. Procedures known to create aerosols must be performed in a biological safety cabinet (BSC). Infectious particles from microorganisms may become suspended in the air; these infectious aerosols may be inhaled by the laboratory worker. These procedures include the preparation

BOX 2-3 Summary of Biosafety Levels (BSLs) for Infectious Agents

Biosafety Level 1 (BSL 1): No known pathogenic potential for immunocompetent individuals. Typical examples include *Bacillus subtilis*. Most undergraduate laboratory courses operate under BSL 1 precautions. Precautions include adherence to standard laboratory techniques.

Biosafety Level 2 (BSL 2): Level 1 practices plus laboratory coats, protective gloves, limited access, decontamination of all infectious waste, and biohazard warning signs. Apparatus includes partial containment equipment (such as classes I and II biological safety cabinets) when procedures may lead to the production of infectious aerosols. This category includes the most common microorganisms associated with laboratory-acquired infections, including HBV, HIV, *Staphylococcus*, and enteric pathogens such as *Salmonella* and *Shigella*.

Biosafety Level 3 (BSL 3): Level 2 procedures plus special laboratory clothing and controlled access are recommended for handling clinical material suspected of containing *Mycobacterium tuberculosis, Brucella, Coccidioides immitis*, *Rickettsia*, and specific viruses such as arbovirus. The air movement must be carefully controlled to contain the infectious materials.

Biosafety Level 4 (BSL 4): Level 3 practices plus entrance through a separate room in which street clothing is changed and replaced with laboratory clothing. Maximum containment includes the use of a class II biological safety cabinet and the decontamination of all personnel and materials before leaving the area. This level is primarily used in research facilities and includes a limited number of exotic viruses including filovirus and arenavirus.

of smears, flaming inoculating loops and needles in the burner flame, vortexing, grinding tissue, and subculturing blood cultures.

BSCs protect laboratory workers from aerosols through **sterilization** by either heat, ultraviolet light, or passage of air through a HEPA filter that removes particles larger than 0.3 mm. Cabinets are classified as class I, II, or III based on performance characteristics with regard to biological containment.

Classes I and II BSCs provide effective partial containment for procedures involving moderate- and high-risk microorganisms or Biosafety Levels 2 and 3 agents. Class I cabinets are open-fronted, negative-pressure, ventilated cabinets. Unsterilized room air enters and circulates within the cabinet, and the exhaust air from the cabinet is filtered by a HEPA filter.

Class II BSCs sterilize both the air entering and circulating within the cabinet and the exhaust air. Type II vertical laminar-flow biological cabinets are open-fronted, ventilated cabinets. Type II cabinets have HEPA-filtered, recirculated airflow within the workspace. The exhaust air from the cabinet also is filtered by a HEPA filter. HEPA filters trap particulates and infectious agents but do not trap volatile chemicals or gases. There are two major types of type II BSCs, based on the inlet flow velocity and percentage of air filtered. Type II-A BSCs are self-contained with 70% of the air recirculated; type II-A BSCs are not required to be vented and are acceptable for low- to moderate-risk agents. A class II BSC is illustrated in **FIGURE 2-3**. Class II type B cabinets must be vented with 30% of the air exhausted from the cabinet and 70% recirculated back into the room.

FIGURE 2-3 Class II biological safety cabinet

Class III BSCs provide the highest level of safety, and all air entering and leaving the cabinet is sterilized with a HEPA filter. Supply air is drawn through a HEPA filter while exhaust air is filtered through two HEPA filters. The system is entirely enclosed, and all infectious materials are handled with rubber gloves that are sealed to the cabinet.

Most hospital microbiology laboratories routinely use class II-A BSCs.

Biosafety Level guidelines as applicable to the microbiology laboratory are found in **BOX 2-4**.

POSTEXPOSURE PLAN

All laboratory accidents or safety incidents must be reported to the laboratory safety officer or supervisor. Appropriate medical treatment must be given immediately. Percutaneous, mucous membrane, or abraded skin exposure to hepatitis B or HIV should be followed climactically and serologically. This includes the administration of immunizations, hepatitis B immune globulin (HBIG), and hepatitis B vaccinations. Collection of blood specimens for serological testing may also be indicated. This includes collection of serum samples at 6 weeks, 3 months, and 6 months for antibodies to HIV or abraded skin exposure to HBV or HIV. Appropriate serological and clinical follow-up of the employee must be provided.

There must be documentation of the accident with a report verifying the incident and follow-up. The accident also should be reviewed to determine how it could have been prevented. Finally, corrective actions must be given so that the accident can be prevented in the future.

Disposal of Hazardous Waste

Microbiological waste must be **decontaminated** before disposal. These waste materials include patient specimens, patient cultures, sharp instruments (needles, lancets) that have been placed in puncture-resistant containers, inoculated media, and other contaminated laboratory supplies. All contaminated materials should be placed into two leakproof plastic bags; double bagging protects against infectious materials from leaking or falling from a single bag. Contaminated pipettes, swabs, and glass should be placed into puncture-resistant burn boxes. Contaminated needles, scalpels, and other implements that have a puncture risk should be placed into sharps containers. The **autoclave** (**FIGURE 2-4**) is often used to decontaminate these materials. The autoclave, which uses saturated steam, is operated

BOX 2-4 Biosafety Level 2 Criteria for Standard Microbiology Practices

1. Limit access to the laboratory when working with infectious agents.
2. Decontaminate work surfaces at least once daily and after any spill of potentially infectious material.
3. Use mechanical pipetting devices.
4. Do not eat, drink, smoke, or use cosmetics in the work area. Store food only in refrigerators so designated that are not in the work area.
5. Thoroughly wash hands after handling infectious materials when leaving the laboratory.
6. Minimize the creation of aerosols in all work procedures.
7. Wear laboratory coats, gowns, or smocks in the laboratory and remove before leaving the laboratory for nonlaboratory areas.
8. Avoid skin contamination by covering cuts in skin with occlusive bandages and using gloves when working with potentially infectious substances.
9. Do not use needles that are bent, cut, or recapped. Used needles should be placed immediately into a puncture-resistant container. Minimize the use of needles for laboratory procedures, such as aspiration of body fluids. A negative pressure may exist between the contents of the bottle and the atmosphere, which may lead to spraying of the contents. A needlestick injury is also a potential consequence in this situation.
10. Handle *M. tuberculosis* at Biosafety Level 3 in a class II biological safety cabinet while wearing a solid-front gown and personal respirator (or face-molding mask). Use sealed safety cups for centrifugation.
11. Handle all mold-like fungi in a biological safety cabinet. All plated media for mycology should be sealed with a cellulose band or cellophane or labeling tape to prevent the dispersion of spores.

FIGURE 2-4 Autoclave

at 121°C and 15 psi (pounds per square inch) of pressure for 1 hour to sterilize most contaminated microbiological materials. All known pathogens, including spores, vegetative cells, fungi, and viruses, are killed under these conditions. Infectious medical waste is usually autoclaved at 132°C for 1/2 hour to 1 hour.

The autoclave must be monitored periodically to measure its effectiveness. *Bacillus stearothermophilus* spore indicator strips, which are quite resistant to the effects of the autoclave, can be used for this purpose. The strips are wrapped in a fashion similar to those articles that are autoclaved. Weekly monitoring is recommended.

Sterilization is a physical or chemical process that kills all microorganisms, including the spores. **Disinfection** destroys most microbes but does not kill the spores.

Biocides are chemical agents that inactivate microorganisms; these agents may be either static and inhibit growth of the microbe or cidal and kill the target organism.

Liquid decontaminants, such as 70% ethanol or a 10% solution of household bleach (sodium hypochlorite), can be used to decontaminate laboratory workbenches. Bleach is

BOX 2-5 Chemical Germicide Categories

1. **Sterilizer:** purpose is to destroy all microorganisms (bacteria, viruses, fungi, prions, viroids) and their spores on inanimate surfaces
   - Moist heat or steam under pressure (autoclave): 121°C for 1 hour at 15 psi of pressure
   - Dry heat: 171°C for 1 hour, 160°C for 2 hours, 121°C for 16 hours
   - Liquid: glutaraldehyde (variable strength), hydrogen peroxide (6% to 30%), formaldehyde (6% to 8%), chlorine dioxide (variable strength)
2. **Disinfectant:** purpose is to destroy or irreversibly inactivate bacteria, viruses, and fungi (but not necessarily the spores) on inanimate objects
   - Moist heat: 75°C to 100°C
   - Liquid: glutaraldehyde (variable strength, bacteriocidal, health care risks including asthma), hydrogen peroxide (3% to 6%), formaldehyde (1% to 8%), chlorine compounds, 70% isopropyl alcohol
   - Liquid household bleach (sodium hypochlorite) can be used as an intermediate-level disinfectant and has bactericidal, fungicidal, virucidal, and tuberculocidal activity. Concentrations of 500 mg to 1,000 mg of chlorine per liter have rapid activity. Concentrations are made based on the nature of the contaminated surface. Porous surfaces should be cleaned with a 1:10 dilution and smooth, hard surfaces with a 1:100 dilution. Time of exposure to the diluted bleach solution may be short. For example, a 1:100 dilution inactivates HBV in 10 minutes and HIV within 2 minutes. Large spills or concentrated infectious agents should be flooded and cleaned with a concentrated (1:5 dilution) solution of bleach. All dilutions should be made up weekly with tap water to prevent the loss of germicidal activity on storage.
   - Quaternary ammonium compounds such as benzalkonium chloride are effective as low-level disinfectants when in concentrated forms. Newer formulations are very effective disinfects with quick activity against bacteria, viruses, fungi, and mycobacteria.
3. **Antiseptic:** chemical germicide for use on the skin or tissues and not to be substituted for a disinfectant
   - **Alcohols:** 70% ethyl or isopropyl alcohol; exhibit rapid broad-spectrum actvity against microorganisms but not against the spores
   - **Iodophors:** iodine combined with an organic carrier molecule; most widely used are povidone-iodine and poloxamer-iodine in both antiseptics and disinfectants
   - **Hexachlorophene:** bactericidal and broad spectrum but may be toxic

an effective antiviral agent and should be in contact with the surface for a minimum of 10 minutes to increase its ability to decontaminate. Contaminated spills first should be diluted with a detergent and then decontaminated. BOX 2-5 summarizes laboratory sterilization and disinfectant measures.

Specimens or infectious materials shipped to reference laboratories must be packaged according to the requirements of the Interstate Shipment of Etiologic Agents code. Specimens must be packaged to protect them in transit and to protect the personnel handling them. Specimens should never be mailed in petri plates and instead should be shipped in thick glass or plastic culture bottles. Culture caps must be sealed with waterproof tape and packed in material that can absorb the entire culture if necessary. This container is then inserted into a second container, usually a metal tube. The second container is inserted into a cardboard mailing tube, which is labeled with an official Etiologic Agents label.

Fire Safety

Ignition sources in the laboratory may include open flames; heating elements; spark gaps, which may result from light switches or static electricity; and electrical

instrumentation. Ignitable liquids include flammable and combustible liquids. When possible, a separate storage room should be used to store these liquids. Flammables and combustibles must be stored in approved containers and should not be stored or positioned by open flames or heat sources. Areas where flammable liquids are used must be properly ventilated for fire protection as well as to protect the laboratory worker. Flammable or combustible liquids may be stored in safety cabinets or safety cans. The supply of these liquids should not be excessive, and up to 60 gallons can be stored in a properly designed safety cabinet (**FIGURE 2-5**) per 5,000 square feet of laboratory space. Up to 25 gallons may be stored in safety cans (**FIGURE 2-6**), while up to 10 gallons may be stored on open shelving per 5,000 square feet of laboratory space.

Flammables should not be stored in refrigerators or within corridors. Transfer of combustible liquids from stock solutions to working solutions must be performed in a storage room when available or within a fume hood. The transport of hazardous liquids should be performed using rubber or plastic safety carriers.

Various types of fire extinguishers (**BOX 2-6**) are available, including dry chemical, carbon dioxide (CO_2), and halon. Solid wood or paper combustibles can be extinguished with water or CO_2, whereas dry chemical extinguishers are needed for flammable liquids. Halon is most suitable for electrical fires, although CO_2 and halon also can be used. Fire blankets and heat-retardant gloves also should be readily accessible within the laboratory. All electrical receptacles must be inspected at least annually. Laboratory instruments and appliances should be checked for electrical hazards at least once every 12 months.

FIGURE 2-5 Chemical storage cabinet

FIGURE 2-6 Safety cans

BOX 2-6 Types of Fires and Fire Extinguishers

Type A, Water Fire Extinguisher

Used on combustible materials for fires in paper, wood, rubber, cloth, and certain plastics. Extinguish fire with cooling effect.

Type B, Carbon Dioxide (CO_2) Fire Extinguisher

Used on extremely flammable liquids or electrical fires including fires of oil, kerosene, or gasoline and some paints, fats, grease, solvents, or other types of flammable liquids.

Extinguish fire by eliminating oxygen.

Type C, Dry Chemical Extinguishers

Used on electrical fires in wiring and other electrical sources or equipment. Extinguish electrical fires because chemicals don't conduct electricity.

Type D, Combustible Metals

Used for fires involving combustible metals, such as sodium, potassium, magnesium, and sodium-potassium alloys. There are a variety of types including sodium-chloride salt which forms a metal layer over the fire which occludes the oxygen. Other types include graphite, sodium carbonate based, and copper based.

Class K, Dry and Wet Chemical Extinguishers

Used for kitchen fires involving combustible materials such as oil or fat.

Extinguish fire by using various wet or dry chemical agents.

Chemical Safety

All hazardous chemicals must be clearly labeled. **Material Safety Data Sheets** (MSDS) outline the characteristics of hazardous compound chemicals. These must be available to all laboratory workers, who are then responsible for following the safety measures given. OSHA dictates the required information for MSDS; this is summarized in BOX 2-7. **Precautionary labels** must be applied to the containers of all hazardous chemicals, including flammables, combustibles, corrosives, carcinogens, and potential carcinogens. The permissible exposure limit, or PEL, is the legal limit for exposure of an employee to a chemical substance or physical agent. It is usually expressed in parts per million (ppm) or in milligrams per cubic millimeter. PEL limits are established by OSHA and are the result of the 1970 Occupational Health Act, which first established OSHA. Short-term exposure limits, or STEL, refer to the maximum limits that a worker can be continuously exposed to a chemical for up to 15 minutes without danger to health.

Hazardous chemicals can be grouped into five categories as follows:

1. **Corrosive**: causes visible destruction or irreversible damage to human skin on contact
2. **Toxic**: serious biological effects after inhalation, ingestion, or skin contact with relatively small amounts
3. **Carcinogenic**: ability of chemical to induce a malignant tumor
4. **Ignitable**: any chemical that can burn and includes both **combustible** and **flammable liquids**
5. **Explosive**: reactive and unstable substances that readily undergo violent chemical change

Individuals who handle chemicals must be knowledgeable about the risks of chemical hazards and must follow established safety protocols. Appropriate preventive measures must be in place and an action plan for exposure must be documented.

Laboratory safety measures prevent transmission of infectious disease and other types of accidents. Students and all laboratory personnel should be knowledgeable of and follow the safety guidelines of their institutions. When an accident occurs, it is important to report and document appropriately.

BOX 2-7 MSDS Required Information

Section	Required information
I	Manufacturer's name and address, emergency telephone number, telephone number for information, date prepared
II	Hazardous ingredient's identity information, components, specific chemical identity common name(s), PEL
III	Physical/chemical characteristics: boiling point, specific gravity, vapor pressure, vapor density, melting point, evaporation rate, solubility in water, appearance and odor
IV	Fire and explosion hazard data: flash point, flammable limits extinguishing media, special firefighting procedures, unusual fire and explosion hazards
V	Reactivity data: stability incompatibility, hazardous decomposition by-products, hazardous polymerization
VI	Health hazard data: route(s) of entry—inhalation, skin, ingestion, health hazards (acute and chronic), carcinogenicity, signs and symptoms of exposure, medical conditions, generally aggravated by exposure, emergency and first-aid procedures
VII	Precautions for safe handling and use: waste-disposal method, precautions to be taken in handling and storing, action if material is released or spilled
VIII	Control measures: respiratory protection, ventilation, eye protection, gloves, work/hygienic practices

Review Questions

Multiple Choice

1. An infection that may occur as a result of accidental needlesticks or through broken glass is classified as which of the following routes?
   a. Airborne
   b. Ingestion
   c. Direct inoculation
   d. Mucous membrane contact
2. Standard precautions state:
   a. Handle only known HBV-positive or HIV-positive specimens as infectious.
   b. Personal protective equipment is required for only direct patient contact.
   c. Blood and body fluid precautions must be observed for all patients' blood and body fluid specimens.
   d. Infectious specimens must be labeled with the biohazard symbol.
3. The Biosafety Level that includes most common laboratory microorganisms and involves organisms such as HBV, HIV, and enteric pathogens is:
   a. BSL 1
   b. BSL 2
   c. BSL 3
   d. BSL 4
4. Which of the following biological safety cabinets sterilize both the air entering and leaving the cabinet and utilize a HEPA filter?
   a. Class I
   b. Class II
   c. Class III
   d. Class IV
5. Autoclave standards for decontamination of most microbiological materials are:
   a. 100°C at 15 psi for 45 minutes
   b. 121°C at 15 psi for 45 minutes
   c. 121°C at 15 psi for 60 minutes
   d. 100°C at 10 psi for 60 minutes
6. Which germicide is intended to destroy all microorganisms and their spores on inanimate surfaces?
   a. Sterilizer
   b. Disinfectant
   c. Antiseptic
   d. Antibiotic
7. Which of the following types of hazardous chemicals causes serious biological effects following inhalation, ingestion, or skin contact with even small amounts?
   a. Corrosive
   b. Toxic
   c. Carcinogenic
   d. Ignitable
   e. Explosive

Discussion

1. List the items of an exposure plan, giving an example of each.
2. Prepare a list of guidelines for laboratory safety to be observed in your microbiology laboratory.
3. Identify the following in your microbiology laboratory:
   a. Sharps containers
   b. Biohazard symbol
   c. First-aid station (or kit)
   d. Eyewash station
   e. Fire extinguisher and fire blanket

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