Maryland STATE DEPARTMENT OF EDUCATION

Maryland Science Safety Manual PK-12

Office of Teaching and Learning

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MARYLAND STATE DEPARTMENT OF EDUCATION

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Acknowledgments

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Many individuals and organizations, both private and professional, graciously donated their time and energy to review versions of this manual during its revision. It is with gratitude and appreciation that we acknowledge the important contributions their reviews made in creating the final document.

Preface

Science safety in Maryland has been rooted in collaboration. The previous Maryland Science Safety Manual PK-12 was a joint project of the Maryland Science Supervisors Association (MSSA) and the Maryland State Department of Education (MSDE). MSDE provided grant funding for the project, which was co-led by MSDE and MSSA. Development of the original Manual began in the spring of 1998 with the organization of a steering committee composed of representatives of the MSSA, MSDE, the Maryland Association of Science Teachers, the Chemical Educators of Maryland, and the Maryland Association of Biology Teachers. The committee outlined the purpose and essential structure for the Manual, compiled a writing team, and gathered the resources to support the project. This work culminated with the completion of the first Maryland Science Safety Manual in 1999.

This updated Maryland Science Safety Manual PK-12 is again a collaboration between MSDE and MSSA. The first step in the process was to have the original manual reviewed by Dr. Ken R. Roy, PhD and Dr. Tyler Love, PhD, experts in STEM safety, for their feedback on required updates. A review committee of teachers and science supervisors was then created to provide additional revisions and reviews. This feedback guided the revision process, ultimately leading to the development of this updated Maryland Science Safety Manual PK-12.

The Maryland Science Safety Manual PK-12 is written to be a comprehensive set of safety guidelines for use by local school systems and schools in providing safe classroom instruction in science. While this manual serves as a guide for science safety in Maryland, each local educational agency (LEA) should develop its own policies specific to its needs based on this document.

We invite all users of this Manual to share ideas for its improvement to the President of MSSA or the Director of Science at MSDE. Such sharing of ideas will continue to ensure that the Manual remains an effective, useful document to guide Maryland's teachers in providing their students with a safe learning environment in science.

Zachary Carey
Director of Science
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Introduction

The three-dimensional nature of the Maryland Next Generation Science Standards weaves together disciplinary core ideas, science and engineering practices, and crosscutting concepts, and highlights the importance of doing science, rather than simply learning about science. The standards emphasize student-centered investigations that include problem solving, sensemaking, data collection, and discovery. Students in science are natural scientists and are eager to explore and ask questions about the world around them. Scientific investigations, engineering design challenges, and place-based learning experiences play critical roles in this approach to science teaching and learning. However, these kinds of learning experiences present a set of risks that need to be anticipated and proactively managed.

Science safety in PK-12 science classrooms should be a priority of central office administration, school administration, and teachers. Safety is the foundation upon which successful scientific inquiry thrives. By fostering a culture of safety consciousness from an early age, we empower students to become responsible stewards of their own learning experiences. Whether conducting experiments in the classroom, exploring outdoor environments, or utilizing cutting-edge laboratory equipment, the principles outlined in this manual will serve as a compass, guiding both students and teachers toward safe and meaningful scientific engagement.

Science safety is not a one-time lesson; it is a mindset, a habit, and a culture that must be ingrained in every facet of our scientific instruction. From the first day of class to the final moments of the school year, the principles of safety should remain steadfast, shaping our actions, decisions, and interactions within the laboratory, classroom, and beyond. The aim is to make safety a part of students' basic approach to the laboratory every day and in all their future scientific and other educational endeavors.

This Manual has been prepared with the objective of supporting the Maryland Next Generation Science Standards and the quality of elementary, middle, and high school science education. Teachers of all science classes will want to refer to several sections to acquire the necessary information across the full range of activities that take place in the science classroom and laboratory. Cross-reference notes guide the reader to sections that provide additional information on a particular safety measure.

This Manual is intended to communicate current best practices for safety in the science classroom and laboratory. Below are several resources that helped guide the development of this Manual:

- Council of State Science Supervisors, Flinn Elementary Science and STEM Safety, https://cosss.org/resources/Documents/CSSS-Elementary-Science-Safety-May-2021.pdf, 2021.
- Council of State Science Supervisors, CSSS Elementary STEM Tool Safety Document, https://cosss.org/resources/Documents/CSSS-Elementary-STEM-Tool-Safety-May-2021.pdf, 2021.
- Council of State Science Supervisors, Science Lab and Prep Area Safety Guidance Resource, https://cosss.org/resources/Documents/CSSS-High-School-Science-Safety-May-2021.pdf, 2021.
- Flinn Scientific Inc. publisher of the Science Catalog Reference Manual, Safety Reference, and Safety website, https://www.flinnsci.com/safety.
- Roy, K. R., & Love, T. S. (2017). *Safer Makerspaces, Fab Labs, and STEM Labs: A Collaborative Guide!* Vernon, CT: National Safety Consultants LLC. ISBN-13: 978-0-692-92408-2

- Stroud, L., Roy, K. R., Doyle, K.S. (2021). *Science Laboratory Safety Manual, 4th Edition*. Vernon, CT: National Safety Consultants LLC. ISBN-13: 978-1-7366120-0-2.
- National Academies of Sciences, Engineering, and Medicine. 2011. *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, Updated Version.* Washington, DC: The National Academies Press.

Some users of the Manual may be governed by regulations established at the school or school system level. Such regulations may supersede the guidelines in this Manual. Some students may also be participating in research or science-related activities in facilities outside of the school system, Career and Technical Education programs, or at colleges or universities. The safety of these students should be governed by the regulations established by these locations, programs, and institutions. Whatever the primary guiding authority, the essential imperative remains: *all who teach and learn in science classrooms and laboratories, as well as those who support these activities, must constantly strive to maintain a safe and stimulating learning environment.*

Chapter 1: Responsibilities

Safety is a shared responsibility. A safe laboratory program requires participation by administrators, teachers, students, and parents.

A. ADMINISTRATORS' RESPONSIBILITIES

1. Provide a laboratory area for science activities that is functional and safe.

2. Provide safety items and ensure that they are in good condition. See Chapter 4, Personal Protective Equipment.

3. Provide for regular inspections of the laboratory, and document inspection and maintenance of safety equipment. See Chapter 6, Safe Handling of Equipment.

4. Ensure that a chemical hygiene plan is developed for the school and that it is accessible to all school staff. See Chapter 7.A, Chemical Hygiene Plan, and Appendix B, Chemical Hygiene Plan (CHP).

5. Ensure that all chemicals used in science laboratories are consistent with local school system guidance. See Chapter 7.B, Managing Chemicals.

6. Comply with federal Hazard Communications Standard (Right-to-Know Law). See Appendix C, Hazard Communications Standard.

7. Ensure compliance with Maryland and Federal regulations for the disposal of excess laboratory chemicals and laboratory waste. See Chapter 7.D, Chemical Waste Strategies.

8. Provide a class size appropriate to the laboratory and in keeping with the recommendations of professional societies. See Chapter 3.A, Class Size.

9. Ensure that all accidents are thoroughly investigated and that, following each investigation, appropriate revisions in safety practices are made as necessary to correct conditions that may have contributed to the accident and to reduce the chances of recurrence.

B. TEACHERS' RESPONSIBILITIES

1. Exercise good judgment in planning for and conducting student laboratory investigations.

    a. Ensure that all students, including multilingual learners and those with disabilities, can participate fully and safely in laboratory investigations.

    b. Set a good example by observing all safety rules, wearing proper protective equipment, and being enthusiastic about safety.

    c. Know the properties and hazards associated with each material used in a laboratory activity before the students carry out the procedure.

d. Ensure that all safety equipment is present in the laboratory and in good working condition. See Chapter 3, Safety Concerns and Safety Equipment, and Chapter 6, Safe Handling of Equipment.

e. Provide eye protection and other necessary personal protective equipment for students and instruct students in the use of such equipment. See Chapter 4.A, Eye Protection.

f. Ensure that all containers are properly labeled with their contents and hazards. See Chapter 7.B, Managing Chemicals.

g. Comply with procedures in the school chemical hygiene plan. See Chapter 7.A, Chemical Hygiene Plan and Appendix B, Chemical Hygiene Plan (CHP).

2. Provide student instruction in safe laboratory procedures in the classroom.

a. Ensure that all students, including multilingual learners and those with disabilities, can safely and effectively engage in safe laboratory procedures by providing clear, accessible, and inclusive instructions. Such instruction should include the location of all classroom safety equipment and safety procedures in a science classroom.

b. Use a variety of instructional methods for diverse student learning, including step-by-step demonstrations, visual representations, and hands-on practice. For multilingual learners, provide instructions in multiple languages, utilize visual aids, model procedures, and offer translations or bilingual support to facilitate comprehension. WIDA Can Do Descriptors describe what multilingual learners can do with language across different content areas. For students with disabilities, necessary accommodations such as accessible materials, adaptive equipment, and tailored guidance to address individual needs. The Disabilities, Opportunities, Internetworking, and Technology (DO-IT) publication *Making Science Labs Accessible to Students with Disabilities* provides many suggestions for ensuring the successful participation of students with disabilities.

c. Have students sign a safety rules agreement. Provide agreements in the student's native language if possible. See Appendix A, Safety Rules Agreement.

d. Instruct and demonstrate to students the use of safety goggles and other appropriate personal protective equipment. See Chapter 5, Safety Strategies in the Classroom.

e. Before each laboratory experiment, instruct students about the hazards associated with each laboratory chemical and activity.

3. Provide appropriate supervision for all classroom instruction, with special attention given to laboratory activities.

a. Make sure that all safety rules are obeyed. See Chapter 5, Safety Strategies in the Classroom.

b. Maintain accountability for laboratory chemicals and materials before, during, and after classroom activities.

c. Promptly clean up or direct the clean-up of spilled materials. See Chapter 7.C, Handling Chemicals.

d. Dispose of laboratory waste properly. See Chapter 7.D, Chemical Waste Strategies.

e. Return laboratory chemicals to a locked storeroom after use.

f. Report any accidents or unsafe conditions in writing to your department chairperson, principal, or other appropriate administrator.

4. Maintain a written record of:

   a. student and parent notification of safe laboratory practices as outlined in the Safety Rules Agreement. See Appendix A, Safety Rules Agreement.

   b. all student instruction in safe laboratory practices.

   c. student infractions of the safety rules.

   d. remedial measures taken to prevent further infractions.

C. STUDENTS' RESPONSIBILITIES

1. Obey all safety rules and regulations and sign a safety rules agreement.
2. Know the location and use of all safety equipment in the laboratory.
3. Understand the experimental procedure before starting to work in the laboratory.
4. Be familiar with the properties and hazards of the chemicals with which you are working.
5. Never remove chemicals, other laboratory materials, or equipment from the science room.
6. Perform only those experiments and procedures authorized by the teacher.
7. Clean your work area immediately after use. Obey good housekeeping practices.
8. Report all accidents and injuries to the teacher immediately.

D. PARENTS' OR GUARDIANS' RESPONSIBILITIES

1. Read the safety rules. Discuss these rules with your student. Sign the Safety Rules Agreement indicating that you have read and understand the rules.
2. Work with the teachers and administrators at your school to develop a strong safety program.

Chapter 2: Legal Aspects of Laboratory Safety

When working in the science laboratory, the safety of the laboratory occupants is of the utmost importance. It is in the best interest of all parties for the classroom teacher, whether in elementary school, middle school, high school, or an outdoor education facility, to take proactive measures, including:

- exercising good judgment in planning, conducting, and supervising instruction;
- maintaining laboratory and safety equipment necessary to carry out instruction safely; and
- documenting that appropriate safety instruction has taken place.

A. SAFETY FIRST

Always document a safety-first program. This could include using and keeping records: of signed rules agreement, results of a safety quiz, pre-laboratory tests with safety questions, a plan book with a notation of the safety rules covered for each laboratory activity on the day the activity was done, safety rules written into a notebook before performing the exercise or operation, and safety rules indicated on any laboratory instruction sheets given to the students.

A reasonable and prudent teacher:

- provides prior warning of any hazards associated with an activity.
- demonstrates the essential portions of the activity.
- provides active supervision.
- provides sufficient instruction to make the activity and its risks understandable.
- ensures that all necessary safety equipment is available and in good working order.
- has sufficient training and equipment available to handle an emergency.
- ensures that the place of the activity is as safe as reasonably possible.

B. FEDERAL AND STATE LAWS

Administrators and teachers must be aware of the requirements imposed by various laws and regulations governing safe environments.

Each numbered paragraph below concerns a law or an agency whose requirements must be met by schools. Although there are areas of overlap, these paragraphs should act as a general statement on the specific areas that are the responsibility of each agency. The abbreviation “CFR” stands for Code of Federal Regulations.

1. **Americans with Disabilities Act (ADA), Section 504 of the Rehabilitation Act, and the Individuals with Disabilities Education Act (IDEA)**

   Public schools are required to comply with provisions of these Federal Laws related to students with disabilities. Under IDEA and Section 504 of the Rehabilitation Act, some students may have accommodations on their Individual Education Program (IEP) or 504 plan for the laboratory settings, e.g., aides who assist the student, extra time to complete the lab work, preferential seating. Students with disabilities are entitled to the same laboratory access as their non-disabled peers. This is true for students with all disabilities with all levels of impact. The Committee on Chemists with Disabilities, American Chemical Society, *Teaching Chemistry to Students with Disabilities, 5th ed* or the Disabilities, Opportunities, Internetworking, and Technology (DO-IT) publication *Making Science Labs Accessible to Students with Disabilities* by Sheryl Burgstahler, Ph.D. are good guides to ensuring that students with disabilities receive the laboratory experience appropriate to access their grade-level standards.

The 2010 ADA Standards for Accessible Design also set minimum requirements – both scoping and technical - for newly designed and constructed or altered State and local government facilities, public accommodations, and commercial facilities to be readily accessible to and usable by individuals with disabilities. This includes safety equipment such as eye wash stations and wall-mounted safety equipment.

2. Occupational Safety and Health Administration (OSHA)

In 1970 the U.S. Congress passed the Occupational Safety and Health Act. The act requires that certain precautions be observed, and certain actions taken to protect the health and safety of employees on the job. Teachers are considered employees under the act, but students are not covered.

Nevertheless, the prudent teacher will conduct the science classroom in such a manner that all occupants follow the regulations. Following OSHA precautions for all classroom or laboratory occupants is good safety practice.

a. **Bloodborne Pathogens.** Concerns about workplace exposures to bloodborne pathogens led the Occupational Safety and Health Administration (OSHA) to issue regulation 29 CFR §1910.1030 in 1991. Employers are required to prepare a plan to control blood-borne pathogen exposure, including the adoption of universal precautions to prevent exposure to blood-borne pathogens such as HIV and Hepatitis B. This statute applies not only to blood but to other body fluids. See Chapter 9.D, Zoology: Animal Considerations.

b. **Hazard Communication Standard (Right to Know).** In 1983 the Federal Hazard Communication Standard (29 CFR §1910.1200) became law. While the law has not changed, periodic addendums have been made. This law requires employers whose employees use toxic substances to provide these employees with (1) safety data sheets (SDS) that describe the properties, safe handling, and health hazards of the toxic materials; (2) labeling of all toxic substances with the product name and a hazard warning; and (3) annual training on the hazards of toxic substances, safe handling procedures, and how to read SDS. The Hazardous Communication Standard is now aligned with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS).

c. **Occupational Exposures to Hazardous Chemicals in Laboratories.** This legislation (29 CFR §1910.1450) requires all employers who are engaged in the laboratory use of hazardous chemicals to appoint a chemical hygiene officer and develop a chemical hygiene plan. The plan should detail how each employee will be protected from overexposure to hazardous materials and describe specific work practices and procedures in the laboratory to minimize employee risk. Students are not considered employees under this law.

3. Environmental Protection Agency (EPA)

The Environmental Protection Agency regulates hazardous waste disposal, including wastes from academic laboratories. One or more sections of the following parts of 40 CFR are of interest to teachers: §261-2, §266, §268, §302, §311, §355, §370, and §372.

4. Department of Transportation (DOT)

Whenever chemicals or hazardous wastes are transported (except between buildings of a single campus), the materials must be packaged following DOT regulations. Sections §171-177 of 49 CFR contain information relevant to school science programs.

5. Maryland Environmental Code

Md. Code, Environment §6-906 prohibits the use or purchase of elemental or chemical mercury in primary of secondary classrooms, which includes mercury filled thermometers.

6. Maryland Education Code

Md. Code, Education §7-407 requires the use of industrial quality eye protective devices for teachers and students while working in a laboratory that involves caustic or explosive chemical or hot liquid or solid.

7. Maryland Criminal Code

Md. Code, Criminal Law §3-806 and §3-807 prohibits the use of a laser pointer to illuminate another in a public place in a manner that harasses or endangers the other or knowingly and willfully shine, point, or focus the beam of a laser pointer on an individual operating an aircraft.

Md. Code, Criminal Law, § 10-614 prohibits – except for commercial breeding or raising – any person from selling or giving away baby chickens, ducklings, or other fowl under three weeks of age.

Chapter 3: Safety Concerns and Safety Equipment

Students need to do science, not just read about science. As an outcome of three-dimensional learning, students will recognize that science is more than a body of knowledge. It is also a way of thinking and a way of investigating. Investigation requires the use of a laboratory environment. Class size, facility design, safety equipment, and fire prevention all must be considered when establishing a safe laboratory environment.

A. CLASS SIZE

Many recommendations from professional organizations identify clear limits on space allocation and the number of students per classroom and laboratory. It is important to not confuse the term "science laboratory" with that of a "science classroom." A science classroom is for lectures/discussion and talking about science. The laboratory is about doing science. This is where the safety standards are most applicable.

Many accidents in the science laboratory can be traced to overcrowding. The correlation between increased class size with increased accident rate has been documented. With more students moving about carrying chemicals and equipment, the risk of an accident increases while direct supervision by the teacher becomes more difficult. A teacher who believes that the laboratory is unsafe due to overcrowding should communicate those concerns in writing to the department chairperson, principal, and science supervisor. Adherence to these guidelines allows for a safe learning environment for students and teachers in science laboratories while facilitating effective, "hands-on" science activities.

1. State-Rated Capacity

The *Code of Maryland Regulations* (COMAR) 14.39.02.04 identifies the State-rated capacity that the Interagency Commission on School Construction (IAC) uses to determine the physical capacity for a school's enrollment.

a. Elementary School Classroom Capacity:

   i. An elementary school classroom is a space where most of the school day is spent in instruction of the core curriculum.

   ii. Prekindergarten classroom — 20

   iii. Kindergarten classroom — 22

   iv. Grades 1 through 5 classroom — 23

   v. Grade 6 classroom — 25

   vi. Special education classroom — 10

b. Secondary School Classroom Capacity:

i. Secondary-school classrooms include laboratories, career technology rooms, music rooms, art rooms, consumer science rooms, gymnasiums (counts as two), and auxiliary physical education classrooms.

ii. Grades 6 through 12 classroom — 25

iii. Special education classroom — 10

2. Recommendations of Science Organizations

a. The National Science Teaching Association (NSTA) position statements recommend that school leaders and teachers should consult research that identifies three safety concerns regarding overcrowding: adult supervision, individual workspace area, and occupancy load for which the space was designed. NSTA states that classes containing more than 24 students engaged in science activities cannot safely be supervised by one teacher. Additionally, research data shows that accidents rise dramatically as class enrollments exceed 24 students or when an inadequate individual workspace is provided (West and Kennedy 2014). NSTA additionally recommends 60 sq. ft. for each secondary student and 45 sq. ft. for each elementary student in a laboratory/classroom setting (Motz, Biehle, and West 2007).

b. The National Association of Biology Teachers (NABT), and the National Science Education Leadership Association (NSELA) agree that the maximum number of students a single teacher can supervise properly in a science classroom is 24.

c. The American Chemical Society (ACS) also supports the recommendations of NSTA for a maximum of 24 students per classroom based on 60 square feet per student for middle and high school chemistry settings.

3. Space Allocation

a. The MSDE Office of School Facilities highly advises against high school science laboratory designs with more than 28 student stations. About 5% of the workstations in a laboratory, but not less than one workstation should be accessible to students with disabilities.

b. The MSDE Science Facilities Design Guidelines (1994) recommend:

i. 35 square feet per student in a general elementary classroom to support science activities with 15 square feet per classroom for general storage.

ii. 35 to 45 square feet per student in dedicated elementary science labs with fixed lab stations and 10 square feet of storage per class served.

iii. a minimum of 36 square feet per student (1008 square feet for 28 students) to a preferred 40 square feet per student (1120 square feet) in a secondary laboratory classroom that houses lab activities.

iv. allowing 14 square feet per student for a lecture area when combined with a lab.

v. 45 square feet per student (1260 square feet for 28 students) in a secondary classroom where both lab and lecture take place at the same tables.

c. Similar guidance is provided to technology classrooms and laboratories in the MSDE Technology Education Facilities Guidelines (2006).

i. For classroom seating areas allow approximately 25 square feet per student (600-700 square feet for 24-28 students), seated at tables.

ii. For small group meeting areas allow a minimum of 20 square feet per person (80-400 square feet for groups of 2 to 10 students) or a 20-person meeting room.

iii. For design areas (4 to 12 students working in pairs) allow 50 square feet per student for drafting tables. Allow 75 square feet per student or 150 square feet for each two-person CAD station.

iv. For research areas (1 to 6 students at a time) allow 25-30 square feet per student but not less than 100 square feet per space.

v. For modular instructional activities areas allow 45 square feet per student or 90 square feet for each two-student modular workstation (1080-1260 square feet for 24 high school students or 24-28 middle school students). A limited middle school program may include only 6-8 modular stations.

vi. For dynamic testing areas 100 square feet minimum for 24 students.

vii. For production/fabrication areas allow 80 square feet per student (480-960 square feet for 6-12 students usually working in pairs).

viii. For teacher offices allow a minimum of 60 square feet per professional but no less than 80 square feet per space.

ix. For material storage allow 80-150 square feet with a 12-foot ceiling height minimum.

x. For project storage allocate 100 square feet (24-28 students at a time up to 150 students per teacher).

xi. For finishing areas allocate 100 square feet.

d. The National Fire Prevention Association (NFPA) defines a laboratory as “an enclosed space used for experiments or tests.” Educational facilities with laboratories have an occupancy load classification as follows:

i. 50 square feet per student in shops, laboratories, and similar vocational rooms; and

ii. 20 square feet per person in a classroom. (NFPA-45 2019).

e. The International Building Code (IBC) identifies the maximum floor area allowances in areas without fixed seats as follows:

i. 50 square feet of floor area per occupant in shops and other vocational areas; and

ii. 20 square feet of floor area per occupant in classroom areas (IBC 2021 Chapter 10, Section 104.5).

B. FACILITIES

1. Emergency Evacuation Route

Emergency evacuation routes should be established for each classroom, laboratory, and storeroom in the school building. Emergency evacuation routes should be accessible to all students and teachers should be aware of any special needs related to their students' egress from the classroom, laboratory, and building. Students should be instructed in the evacuation plans for any rooms they may occupy while at school.

2. Master Cut-off Switches

a. Master gas, electric, and water cut-offs should be readily accessible and any teacher using the laboratory or science prep room should be aware of their location.

b. The cutoffs should be mounted high enough that they cannot be accidentally activated.

c. The cutoffs should be located near each other for ease of control during an emergency.

d. In the event of a fire or electrical accident, shut off the gas and electricity in the laboratory.

3. Emergency Communication

Teachers should be able to use a telephone or intercom to contact administrators or the school nurse in the event of an emergency during a lab activity.

4. Signs and Labels

Ensure that all signs and labels are in any language spoken by the students using the laboratory. Add visuals or use pictograms to communicate hazards whenever possible. The following signs and labels should be posted in prominent areas of the laboratory and adjoining rooms:

a. Emergency telephone numbers.

b. Laboratory safety rules.

c. In chemical storerooms, the National Fire Protection Association (NFPA) diamond with the highest hazard ratings of the materials in the rooms. See Appendix E, NFPA Identification Codes.

d. Labels indicating types of hazardous contents of cabinets.

e. **NO FOOD** labels on refrigerators in storerooms used for storing chemicals or biological materials.

f. Clearly label foodstuffs intended for laboratory exercises: **NOT FOR HUMAN CONSUMPTION**.

g. Non-Potable Water signs at lab sinks.

h. Location signs for:

- fire extinguishers
- fire blankets
- eyewash station
- safety shower
- spill kits
- goggle cabinet
- waste containers (e.g., chemical, broken glass)
- master gas and electric cutoff

5. Students with Disabilities

The 2010 ADA Standards for Accessible Design set minimum requirements – both scoping and technical – for newly designed and constructed or altered State and local government facilities, public accommodations, and commercial facilities to be readily accessible to and usable by individuals with disabilities. This includes access to safety equipment such as eye wash stations (2010 ADA 602) and wall-mounted safety equipment, first aid kits, google cabinets, etc. (2010 ADA 307). There may be a need to purchase adapted safety and lab equipment as appropriate to student needs. A student's IEP or 504 plan will typically note if they require adaptive equipment, but if a teacher thinks a student may require additional equipment they are encouraged to reach out to the school's special education administrator or IEP chair.

Science laboratories, like other school facilities, should be accessible and safe for students with disabilities, including students with mobility impairments. The teacher should be aware of any required support related to the students' egress from the laboratory and building in case of an emergency. A student's IEP or 504 plan will note if a student requires specific accommodations in the event of an emergency evacuation.

C. FIRE SAFETY AND FIRE CONTROL

In the event of a fire, remember that the personal safety of the building's occupants must always be the priority. The teacher should know the location and how to use the nearest fire alarm box, as well as follow school system procedures for the use of (or direction of emergency personnel to use) any fire extinguishers, fire blankets, or other firefighting aids that may have available in the classroom. If a person's clothing or hair catches on fire, have the person stop, drop, and roll on the floor to suffocate the flame or use a safety shower. Do not use fire extinguishers on people.

D. SAFETY EQUIPMENT

1. Eyewash Stations

Eyewash stations are essential in areas where chemicals are used. Caustic chemicals can damage the eye within seconds of contact. Based on the American National Standards Institute (ANSI Z358.1-2014) eyewash stations should:

- treat both eyes simultaneously.
- provide a minimum flow of water of 0.40 gallons per minute at 30 pounds per square inch for at least 15 minutes.
- be accessible within 10 seconds (55 feet) from the time of injury.
- be capable of being activated in 1 second or less.
- accommodate hands-free rinsing to hold eyelids open.
- have dust caps or dust covers installed to protect the unit from contamination.
- have spray heads positioned between 33" and 45" from the floor.

ANZI also recommends that all plumbed eyewashes be activated weekly for a period long enough to verify operation and ensure that flushing fluid is available (approximately 3 minutes) and inspected once a year for compliance with standards. A maintenance record should be maintained.

The 2010 ADA 602: Drinking Fountains requires newly designed and constructed or altered schools to have clear space for wheelchair approach to drinking fountains, which serves as a guide for eye wash station approach requirements. Additionally, the controls and operating mechanisms for the eye wash station must be within the appropriate reach range identified in 2010 ADA 308: Reach Ranges.

Portable eyewash squeeze bottles are not an acceptable alternative because they can treat only one eye, provide an inadequate water supply, are susceptible to contamination, and provide a good environment for the growth of microorganisms.

2. Fire Blankets

a. Fire blankets of flame-retardant wool or woven fiberglass and felt are useful for smothering small fires as well as keeping accident victims warm. They may be rolled or folded and kept in wall-mounted cases.

b. Fire blankets manufactured before 1970 contained or were sprayed with asbestos and should be removed from the classroom.

c. For clothing fires, fire blankets should be used with caution. The best method is the "stop, drop, and roll" method.

3. Fire Extinguishers

a. Most science and STEM laboratories contain chemicals and electrical wiring that could cause smoke or fires. For this reason, the National Fire Protection Association's NFPA 45-2019 (section 6.3) standard, in accordance with NFPA 10-2022, requires portable fire extinguishers to be installed and maintained in most laboratories.

The exception to these standards would be laboratories that contain less than 4 L (1 gallon) of flammable or combustible liquid and less than 2.2 standard m^3 (75 standard cubic feet) of flammable gas, not including piped-in low-pressure utility gas.

b. Fire extinguishers must comply with the area of coverage and travel distance criteria. Different types of fire extinguishers are designed to handle different types of fire. The three most common types of fire extinguishers are air-pressurized water, carbon dioxide, and dry chemicals. Fire extinguishers are identified to work on different classes of fires.

- Class A: ordinary combustibles such as wood, paper, and plastics.
- Class B: flammable liquids such as oils, greases, oil-based paints, and some plastics.
- Class C: electrical equipment such as wires, circuit breaker panels, appliances, and computers.
- Class D: combustible metals such as magnesium, potassium, sodium, and lithium.
- Class K: vegetable oils, animal oils, and fats in cooking appliances

c. The best extinguisher for a typical science laboratory is a multipurpose extinguisher which will work on class A, B, and C fires. Special Class-D extinguishers are recommended as an additional safety measure for handling rare Class-D fires if combustible metals are present. (Some types of fire extinguishers can aggravate a Class-D fire.)

4. First Aid

a. Every school should have a safety and first aid plan.

b. Each school should have a first aid station for providing basic first aid and stabilizing students who will be transported to a medical facility.

c. Each laboratory should have a standard first aid kit stocked according to school policy and recommendations of the school nurse.

5. Safety Shields

Portable safety shields should be used for protection against hazards of limited severity, such as small splashes, heat, and fires. Use these shields with the knowledge that they do not protect the back and sides. If possible, the shield should be attached to the surface on which it is placed (by clamps).

6. Safety Showers

A safety shower should be available in every laboratory where chemicals are used. The shower is used to wash hazardous chemicals from the skin and clothes. Based on the American National Standards Institute (ANSI Z358.1-2014) safety showers should:

- be accessible in no more than 10 seconds (about 55 feet) from the site of the emergency.
- provide a minimum flow of 20 gallons per minute for up to 15 minutes.
- be capable of being activated in 1 second or less.
- be designed so that valves remain open without the use of hands until intentionally closed.
- have a control to operate no more than 69 inches above the standing surface.

The safety shower should be tested, and the tests recorded periodically following the school safety plan or as directed by the manufacturer.

Dimensional parameters for accessible safety showers can also be determined from the 2010 ADA Standards considering protruding objects (2010 ADA 307) and reach range (2010 ADA 308) guidelines.

A hand-held sprayer with a six-foot hose is a viable alternative for small spills that frequently occur in the teaching laboratory. Such a sprayer should be a supplement and not a replacement for a plumbed safety shower.

7. Spill Kits

A spill kit should be accessible in each science classroom or laboratory. The kit might include:

- spill control pillows (which are commercially available)
- inert absorbents such as vermiculite, clay, sand, or kitty litter
- neutralizing agents for acid spills such as sodium carbonate and sodium hydrogen carbonate
- neutralizing agents for alkali spills such as sodium hydrogen sulfate and citric acid
- large plastic scoops and other equipment such as brooms, buckets, bags, and dust pans
- appropriate personal protective equipment (PPE)

E. VENTILATION

1. Room Ventilation

Adequate ventilation is important in any room in which chemicals are used or stored. According to the *NSTA Guide to Planning School Science Facilities* (2007), the air in a science laboratory should be changed a minimum of eight times per hour. Chemical storerooms or animal storage areas should have ventilation adequate to change the air twelve times per hour. NFTA 45-2019 also indicates that exhaust from chemical storerooms and fume hoods should not be recirculated and should be continuously ventilated under normal operating conditions.

2. Fume Hood

Fume hoods are the most important equipment used to protect teachers and students from exposure to hazardous chemicals and agents used in the laboratory. Review the 2010 ADA Standards to ensure that the hood and its operable parts are accessible to students and teachers with disabilities.

a. Location – Hoods and the safety shower/eye wash stations in the laboratory should be separated by 15 to 20 feet to allow the safety equipment to be used in the case of accidental discharge of fumes from the hood. To maintain the effectiveness of the hood avoid locating it in proximity of foot traffic, particularly at the entrances or exits to the laboratory.

b. Velocity - A face velocity of 60-120 fpm (the average velocity of air drawn through the face of the hood with the sash open 6 inches) should effectively remove fumes produced within the hood, conditional on proper placement and use.

c. Use – Hoods are only effective in removing contaminants situated directly under the hood. They do not serve to clean the air in the general environment of the laboratory.

i. Do not store chemicals in a fume hood for prolonged periods. Instead, store chemicals in the proper safety cabinet or storeroom.

ii. Fume hoods must be inspected for proper use. Devices are available to measure face velocity.

iii. When using the fume hood keep the sash at its lowest position no higher than 18 inches. It should never be fully open except during maintenance.

iv. Work as far inside the hood as possible but keep your head outside the hood. A minimum working distance of 6 inches from the front of the hood is recommended.

v. When the fume hood is not in use the sash should be kept closed.

d. Ductless - Ductless fume hoods are not an acceptable long-term alternative for traditional ventilated fume hoods because they do not offer the same level of protection as traditional ventilated fume hoods. They do not remove all chemicals from the laboratory and may cause exposure to hazardous chemicals.

i. The filter used limits the type and amount of chemicals that can be used in the fume hood. For example, a HEPA filter only removes particulates, not chemicals, and a carbon/charcoal filter will not efficiently capture some flammable gases.

ii. Only small quantities of chemicals can be used in the fume hood to prevent filter saturation in the case of a spill.

iii. The filter needs to be changed on a regular schedule of bimonthly to every six months depending on the fume hood usage to prevent saturation of the filter.

iv. Depending on the filter and chemicals used in the fume hood, the filter may need to be disposed of as hazardous waste.

Chapter 4: Personal Protective Equipment

Providing a safe laboratory environment involves a combination of many efforts. In addition to proper training, procedures, ventilation, and emergency equipment, it is important to provide teachers and students with proper personal protective equipment (PPE). Students whose disabilities impact their sensory processing may need assistance or a plan in learning to tolerate some commonly used PPE, such as goggles, lab coats, or masks.

A. EYE PROTECTION

The most vulnerable part of the body is the eye. Md. Code, Education §7-407 requires the use of industrial quality eye protective devices for teachers and students while working in a laboratory that involves caustic or explosive chemical or hot liquid or solid.

1. Safety Goggles

a. Teachers, students, and visitors must wear safety goggles at all times during laboratory work since the student – and sometimes even the teacher – cannot reliably judge the presence of risk.

b. The teacher has the responsibility to train and demonstrate to students the proper use and care of safety goggles.

c. Safety goggles must meet minimum standards for the design, construction, and quality of eye protective devices. Any eye protective device used in such school laboratories should be designed and constructed to:

   i. resist impact;

   ii. protect against the particular hazard for which it is intended;

   iii. fit snugly without interfering with the movements of the user; and

   iv. be durable, cleanable, and capable of frequent disinfection.

d. Safety glasses are not an acceptable substitute for chemical splash safety goggles in most science laboratories because they protect from impact only and not from chemical splashes.

e. All indirectly vented splash goggles and safety glasses with side shields need to comply with one of the following standards per OSHA 1910.133 as applicable: ANSI Z87.1-1989, ANSI Z87.1-2003, ANSI/International Safety Equipment Association (ISEA) Z87.1-2010. The most recent edition of the American National Standard used for safety glasses, safety goggles, side shields, and other eye and face protection devices is ANSI/ISEA Z87.1-2020: Occupational and Educational Personal Eye and Face Protection Devices.

f. Keep the lenses clean. Dirty lenses obscure vision and may lead to eye fatigue. Never clean lenses with abrasive hand soap, since it will scratch them. When cleaning plastic lenses, any abrasive dirt that may be on the surface should be flushed off by holding the lenses under running water; otherwise, the lenses will become scratched by the abrasive matter being rubbed into the lenses. Glass lenses with surface scratches should be replaced since the hardened glass has thus been weakened.

g. If safety goggles are used by multiple classes, sanitize them between each class by:

  i. placing the goggles in an Ultraviolet (UV) cabinet for 5-15 minutes between classes.

  ii. wiping the goggles with a quaternary ammonium-based disinfectant (such as CaviWipes, Clorox Disinfecting Wipes, or Lysol Disinfecting Wipes) according to the manufacturer's directions. Allow time to dry before the next use.

  iii. washing the goggles in soap or dish liquid and warm water. A dishwasher with detergent could also be used to wash the goggles. Allow time to dry before the next use.

2. Face Shields

a. Full face shields protect the face and neck better than goggles.

b. Face shields are not a substitute for chemical splash safety goggles.

c. When maximum protection from flying particles and harmful liquids is needed, face shields should be worn with goggles.

3. Contact Lenses

Wearing contact lenses in the laboratory is a complicated issue. Teachers may recommend that students not wear contact lenses, or they may allow selected and identified students to wear them. The following are important considerations in deciding about and governing the use of contact lenses.

a. Soft contact lenses can absorb chemical vapors.

b. Students who are not wearing their corrective eyewear (contact lenses or prescription glasses) may present a different type of hazard because of their limited vision.

c. Students who wear contact lenses should be required to wear chemical splash safety goggles.

d. If a student wearing contact lenses spills or splashes harmful chemicals in their eyes, the contact lenses must be removed immediately, and the eyes flushed with water.

4. Lasers

The greater a laser pointer's output power, the more likely it will cause serious eye injuries, burn skin and temporarily, or permanently, impair vision. Laser pointers that can be purchased sometimes lack labels or have inaccurate labels and are overpowered compared with what the label says. See Chapter 11.G, Laser Safety, for information on eye protection when working with lasers.

B. GENERAL GUIDELINES FOR DRESS IN THE LABORATORY

1. Be aware of and respect cultural differences when dealing with appropriate laboratory dress. Typically, a compromise can be achieved by using PPE over the clothing and does not require the student to remove any culturally required item.
2. Loose fitting, frilly, or highly flammable clothing should not be worn in the laboratory. Ties or scarves should be tucked in.
3. Sandals, open-toed shoes, and shoes with canvas or mesh uppers should not be worn in the laboratory.
4. Long hair and loose clothing or jewelry must be confined when working in the laboratory.
5. Finger rings should not be worn while working with chemicals or equipment that has moving parts. Rings can react with chemicals or puncture laboratory gloves. Chemicals can get trapped under rings and irritate the skin.

C. BODY PROTECTION

1. Aprons

a. Aprons should be worn during all chemistry laboratory work.

b. Rubber-covered muslin aprons provide good protection from corrosive or irritating liquids.

c. A plastic apron can accumulate a considerable charge of static electricity and should be avoided in areas where flammable solvents or other materials could be ignited by a static discharge.

2. Gloves

a. Gloves should be worn whenever it is necessary to handle corrosive materials, rough or sharp-edged objects, extremely hot or very cold materials, or whenever protection is needed against accidental exposure to chemicals.

b. Gloves should not be worn around moving machinery.

c. Many diverse types of gloves are commercially available. Consult a laboratory supply catalog for descriptions of the several types available and their specified uses.

d. Consider student allergies to latex when purchasing gloves.

e. Before each use, gloves should be inspected for discoloration, punctures, and tears.

f. Before removal, gloves should be washed appropriately. (NOTE: Some gloves, including those made of leather and polyvinyl alcohol, are water permeable.)

g. Glove materials are eventually permeated by chemicals. However, they can be used safely for limited periods if specific use and glove characteristics (i.e., thickness and permeation rate and time) are known. Some of this information can be obtained from glove manufacturers.

h. Gloves should be replaced periodically, depending on the frequency of use and permeability to the substance(s) handled.

3. Laboratory Coats

Laboratory coats are intended to prevent contact with contaminants and the minor chemical splashes or spills encountered in laboratory work. The cloth laboratory coat is, however, primarily a protection for clothing and may itself present a hazard (e.g., combustibility) to the wearer. Cotton and synthetic materials are satisfactory, but rayon and polyesters are not. Laboratory coats do not significantly resist penetration by organic liquids and, if significantly contaminated by them, should be removed immediately.

4. Respiratory Protection

Federal regulations prohibit the use of respirators by untrained personnel or students (29 CFR 1910.134). Activities that require the use of respirators should not be performed in a classroom laboratory setting.

Chapter 5: Safety Strategies in the Classroom

Safety in the science laboratory requires common sense, preparation, and knowledge by teachers and students.

Teachers make their laboratories safe by:

- planning and implementing instruction that provides all students, including multilingual learners and those with disabilities, with the information they need to conduct laboratory investigations safely.
- ensuring that functioning safety equipment is readily accessible in the laboratory.
- modeling compliance with safety rules and using the proper protective measures.
- supervising students to ensure that safety rules are obeyed.
- documenting all student instruction in laboratory safety.

Following best practices ensures the safety of students, teachers, and staff in any lesson they teach (NSTA position statement Liability of Science Teachers for Laboratory Safety, 2017). Best practices include:

- Notify Students of Safety Practices and Procedures
- Model Safety
- Warn of Dangers and Hazards
- Inspect for Safety
- Enforce Safety
- Maintenance

For this reason, teachers should always be certain that they are prepared to complete a safety hazard assessment and address any safety issues that arise with any science lesson they teach. Teachers and instructors should be thoroughly familiar with the science content related to any hands-on activities that they assign to students.

Teaching students the proper way to handle materials in the school laboratory should also help them learn the correct handling of chemicals found at home or on the job.

Good safety instruction must be continuous throughout the year. Emphasize safety practices on the first day and reinforce the concepts at the start of each experiment. Teachers should lead by example and wear personal protective equipment; follow and enforce safety rules, procedures, and practices; and demonstrate safety behavior and promote a culture of safety. A successful science safety program begins with the teacher’s belief in safety as an integral part of science instruction.

A. SAFETY GUIDELINES FOR TEACHER

1. Safety Rules

Teachers should follow safety guidelines from their school system and share these with their students. The rules and sanctions should be spelled out in a rules agreement that is signed by the students and parents or guardians. Provide agreements in the student's native language if possible. Signed copies of the agreement should be kept on file according to the policies of the school system and its Chemical Hygiene Plan. At a minimum, the agreement should be kept for the entire school year the student is in the science class. This can help make students aware of their responsibility for safety and the seriousness of the matter. See Appendix A, Safety Rules Agreement.

2. Safety Quiz

Teachers should administer a safety quiz to assess their understanding of safety rules and procedures. Provide the safety quiz in the student's native language if possible.

3. Safety Instructions

Teachers should include safety concerns and precautions specific to each topic or experiment as part of their lessons throughout the year. When appropriate, require students to include safety information in laboratory written work such as a statement or paragraph indicating the safety equipment used and safety practices followed. Students' compliance with safe techniques and practices may become part of a teacher's evaluation of laboratory work. A record of this evaluation should be included in the teacher's lesson plan as legal proof of this additional safety instruction.

Use a variety of instructional methods for diverse student learning, including step-by-step demonstrations, visual representations, and hands-on practice. For multilingual learners, provide instructions in multiple languages, utilize visual aids, model procedures, and offer translations or bilingual support to facilitate comprehension. For students with disabilities, necessary accommodations such as accessible materials, adaptive equipment, and tailored guidance to address individual needs.

4. Posters and Signs

Posters highlighting the safety rules and techniques are effective reminders to students and all who enter the laboratory. Ensure that all signs are in all languages spoken by the students using the laboratory.

5. Chemicals

Teachers must be familiar with the chemicals, equipment, and procedures they are using. As required by the chemical hygiene plan in each school, a file of Safety Data Sheets (SDSs) must be kept in alphabetical order. See Appendix C, Hazard Communications Standard

Teachers should have a thorough understanding of the potential hazards of materials, processes, and equipment used in their laboratories. Teachers should always perform classroom experiments before assigning them to a class. Such preparation will allow teachers to break down the laboratory into stages, determine the hazards for each stage, and establish precautions to avoid these hazards.

Teachers can reduce students' exposure to harmful chemicals by selecting and using those that pose a minimum risk. Please consult the Carolina website for examples of chemicals that are more hazardous than their potential educational utility. Teachers are responsible for training students in the proper handling of chemicals. Training should include the importance of:

a. safe storage of chemicals and proper disposal of chemical waste.

b. using a ventilation (fume) hood for any experiment that may generate hazardous or irritating fumes.

c. smelling substances by wafting the fumes toward the nose with a cupped hand.

d. pouring corrosive chemicals from their containers by using a stirring rod. If chemicals drip down the sides, clean the bottle before picking it up.

e. taking care with bottle stoppers. Stoppers placed near a spill or returned to the wrong bottles could have unexpected and dangerous results. Penny-head stoppers must be removed from the bottle by grasping between the index and middle fingers with the back of the hand toward the bottle. The same hand can then be used to hold the bottle and pour it into the target container.

See Chapter 7, Chemical Management, Handling and Disposal.

6. Safe Laboratory Protocols

To support safer experiences in the laboratory, teachers should:

a. Circulate among students to monitor students' work and to better ensure swift response to emergencies or incidents.

b. Remain present and attentive in the laboratory at all times when students are working and do not let students work alone or unattended.

c. Ensure students understand instructions before the students begin work. Teachers should inform students about the special hazards and precautions associated with specific experiments.

d. Allow sufficient time for student performance. Rushing students often causes accidents.

e. Model proper safety conduct for students to follow.

f. Ensure that students are wearing the appropriate personal protective equipment (i.e., chemical splash goggles, lab aprons or coats, and gloves).

g. Never permit food or beverages in the laboratory.

7. Safety Practices

To support safer supervision within the laboratory, teachers should:

a. Complete the required safety training provided by their school system each school year.

b. Substitute less hazardous chemicals whenever possible to improve laboratory safety and minimize the need to dispose of hazardous waste (See Chapter 7.D, Chemical Waste Strategies.)

c. Carefully scrutinize the use of older books and laboratory manuals as sources of experiments because laboratory practices may have changed over time based on updated safety guidelines.

d. Consult reputable safety resources such as the NSTA Safety Blog, science journals, and publications to keep current on safety techniques.

8. Good Housekeeping and Safe Storage

The teacher must maintain strict control of access to chemicals. Chemical storage rooms and cabinets should be locked and access restricted. Teachers should not leave storage containers of chemicals in the classroom during an activity. Students should have access only to the chemicals and quantities needed. Locking up the laboratory when it is not in use is important to prevent unauthorized experimentation or theft.

Good housekeeping can make a significant contribution to safety in the laboratory.

a. Setup

i. Making sure that laboratory benches and tables are scrubbed frequently so that spilled chemicals will not injure either the students or equipment. Materials must be kept clean and orderly. It is important to eliminate the possibility of the residue of one experiment being present in an apparatus when the next experiment is conducted. The combination of chemicals might be dangerous.

ii. Prohibiting students from handling or working with broken glass. Inspect all glassware before use in the laboratory.

iii. Arranging seats to allow safe and quick exit in the event of an emergency. Aisles should be unobstructed, and access to safety equipment such as fire extinguishers or safety blankets must not be blocked.

b. During Cleanup

i. Setting a clear expectation for safe laboratory cleanup from the first laboratory session. Proper cleanup includes keeping all laboratory areas, sinks and implements clean, neat, and orderly.

ii. Establishing a procedure for "checking" students out of the laboratory at the end of an experiment or class period. Teachers should make sure students have cleaned up properly and have not left any hidden dangers. Materials and equipment should also be checked.

iii. Holding each student responsible for cleaning up their area and materials. Teachers and students should help each other with cleanup.

iv. Assigning individuals or teams to take charge of shared areas and checking on the return of items used in the laboratory activity.

v. Scanning shared areas such as sinks and supply tables several times during the period. If the condition of any of these areas is unsatisfactory, the teacher should stop the activity and supervise the cleanup of the area or areas before allowing students to resume their laboratory assignment.

vi. Including time for cleanup in the regular lesson schedule.

vii. Complimenting students if things look good or cleanup was performed quickly and efficiently.

viii. Requiring students to return to their seats after cleanup, scanning the laboratory and equipment, and not dismissing students until all is in order.

c. Storage

i. Storing glassware on drying racks or open shelves. Allowing water to evaporate saves time and paper towels.

ii. Labeling shelves and trays so students can tell where to return materials.

iii. Making sure that cabinets and drawers are closed when not in use.

iv. Making sure that waste is deposited in appropriate receptacles.

v. Keeping the area under all fume hoods free of clutter at all times. Fume hoods should not be used for storage.

vi. Making sure that fragile and bulky equipment is stored in a manner that minimizes the chances of brushing or jarring it off the shelf. Shelves with raised edges are recommended for equipment storage.

See Chapter 7.D, Chemical Waste Strategies.

9. Accidents

Be alert to the possibility of an accident. Know where all safety equipment is located and how it works. Know the location of emergency cutoff switches or valves for gas and electricity. Check all physical facilities and equipment to ensure maximum safety conditions. Take prompt action to report and correct unsafe conditions. See Chapter 5.C, Response to Injuries. See also Chapter 3, Safety Concerns and Emergency Laboratory Equipment, and Chapter 6, Safe Handling of Equipment.

B. SAFETY RULES FOR STUDENTS

The following general safety precautions for students supplement those found in other chapters. Students should:

- know the location of safety and first aid equipment, including fire extinguisher, safety shower, fire blanket, and eye wash.
- never engage in horseplay or other acts of carelessness.
- dispose of waste properly. Do not put matches in the sink.
- notify the teacher about broken glassware so the teacher can collect and discard it in the proper container.
- never eat or drink in the laboratory.
- never drink from laboratory glassware.
- notify the teacher when observing hazardous conditions in the classroom.
- examine equipment for malfunction, cracks, or other defects before beginning.
- report all accidents, no matter how minor, to your teacher immediately.
- know the possible hazards for each experiment before conducting it.
- perform only authorized and approved experiments.
- follow instructions explicitly.
- ask for clarification if at any time experimental procedures are unclear or confusing.
- prepare for an experiment by reading the directions before you come to the laboratory.
- set up equipment away from table edges to avoid dropping it on the floor.
- wash hands after all spills and at the end of each laboratory period.
- read all labels twice before using any chemical.

- never return excess chemicals to the stock bottle; discard any excess according to approved procedures.
- never mix chemicals unless the teacher or experiment directions instruct you to do so.
- never taste chemicals.
- always add acid to water (with vigorous stirring), not vice versa.

See Appendix A, Safety Rules Agreement, for a more complete list of rules. See also Chapter 4, Personal Protective Equipment, Chapter 5, Safety Strategies in the Classroom, and Chapter 6, Safe Handling of Equipment, for specific laboratory and equipment handling rules.

C. RESPONSE TO INJURIES

1. General Procedures

Emergency procedures should be established at the beginning of the school year and conspicuously posted in your classroom. Teachers must follow emergency policies and procedures established by their LEA. Below is a sample of some general procedures:

a. In the event of a student injury, the established emergency procedure should direct teachers to:

   - contact the school nurse or other school staff trained in emergency medical treatment or outside medical personnel.
   - call 911 as needed for additional medical assistance.
   - notify the school administration.
   - keep the injured student calm and comfortable while awaiting the arrival of medical assistance.
   - notify the injured student's parents or guardians immediately according to the school system's procedures.

b. School administrators should strongly encourage parents or guardians of injured students to seek follow-up care for the student from medical specialists.

c. Safety equipment should be located in a prominent place and clearly identified with signs.

See Chapter 3.B, Facilities, and Appendix C, Hazard Communications Standard, for additional information on emergency procedures.

2. Responses to Specific Types of Injuries

Follow the school or school system's safety or first aid plan for specific injuries. Below are several possible injuries that could occur in the lab and school personnel should have training for initial first aid until trained medical personnel arrives on the scene.

a. *Bleeding*. After putting on a pair of nitrile gloves or the equivalent, hold a clean cloth pad directly over the wound and apply hand pressure. A tourniquet should not be applied.

b. *Chemical Burns*. A chemical burn is a severe injury involving the destruction of tissue following contact with strong acids, alkalis, or oxidizing materials. Affected areas of skin should be promptly and freely flushed with water for at least 15 minutes. Contaminated clothing should be promptly removed. Copious flushing with water is necessary to remove (mechanically or by dilution) all injurious materials. Do not consider chemical antidotes as the reactions could produce further injury. Check the SDS sheet for possible delayed effects.

c. *Clothing Fire*. The student whose clothing is on fire should drop to the floor and roll. If the safety shower is immediately available, it may be used to douse the flames. The teacher should calm the student since running in panic fans the flames and can result in more serious burns.

d. *Eye Injuries*. Splashes of chemicals or exposure to vapors of some chemicals should be thoroughly flushed with an eye wash. Eyelids should be held apart so the entire surface of the eye may be flushed. Flushing should be continuous for at least fifteen minutes. Contact lenses, if worn, should be removed prior to flushing the eyes. See Chapter 4.A, Eye Protection.

e. *Poisoning by Inhalation*. Certain vapors, fumes, mists, or dusts can cause injury if inhaled. If such an injury occurs, remove the student from exposure as quickly as possible and move him or her to fresh air. If breathing has stopped, begin artificial respiration.

f. *Swallowed Poisons*. If a student swallows an acid or base, quickly give the student copious amounts of water to drink to dilute the substance. For other materials, follow the instructions on the label. Never give liquids to an unconscious person.

g. *Thermal Burns*. Immerse the burned area in cool water. Continue immersion until the pain is relieved and does not return when the burn is removed from the water. Prompt application of cold eases the pain and tends to reduce the severity of the burn. In the case of serious burns, cover the burned area with sterile gauze or a clean sheet until medical personnel arrive.

h. *Allergic Reactions*. Contact emergency personnel. If the student has a known allergy see if they have an epinephrine (adrenaline) auto injector and help them with it if needed. Lie the student down on their back. Raise their feet about 12 inches and cover them with a blanket. Turn the student to their side if they are vomiting or bleeding. Make sure their clothing around the neck and chest is loose so they can breathe.

D. STUDENT SCIENCE LABORATORY AIDES

Teachers are responsible for the well-being of students assigned to them as aides. A student should not be accepted in this role unless the teacher knows the student to be responsible and trustworthy. Students selected to serve as aides should complete all required safety training and sign safety rules agreements before beginning work as aides. In assigning tasks to an aide, the teacher should alert the aide to potential hazards and how to avoid them. It is suggested that the teacher maintain a log of each student aide's assignments. In addition, a chart of general safety regulations should be posted in the preparation room for aides to follow. At no time can an aide substitute for a teacher, nor should an aide work unsupervised. The teacher has the same responsibilities in supervising an aide as in supervising other students.

Chapter 6: Safe Handling of Equipment

Proper use and maintenance of laboratory equipment are essential to laboratory safety. Equipment should be regularly inspected to ensure proper maintenance. Many laboratory accidents can be attributed to improperly maintained or improperly used laboratory equipment.

A. GLASSWARE

1. **Type -** Use the correct type of glass.

    a. When heating glassware, make sure to use only glassware made of borosilicate glass that complies with the American Society for Testing and Materials (ASTM) E-438 Type 1, Class A Standard Specification for Glasses in Laboratory Apparatus. All Pyrex®, Kimax®, Quickfit®, SVL® and many MBL® and Wheaton® products are manufactured from low expansion borosilicate glass. Common glass can break, explode or shatter very easily when subjected to heat shock.

    b. Make sure to use test tubes made of borosilicate glass when heating. Not all test tubes are made of borosilicate glass.

2. **Proper Use -** Each type of glassware has its proper use and should be used only for its intended purpose.

    a. For measuring volume:

        - pipets
        - burets
        - graduated cylinders
        - volumetric flasks
        - dropper pipets ("medicine droppers")

    b. For storing solids and liquids:

        - bottles
        - vials

    c. For containing reactive chemicals during experiments:

        - beakers
        - test tubes
        - flasks
        - watch glasses

- test plates

d. For transferring liquids and gases:

- glass tubing
- plastic tubing
- funnels

e. For measuring temperature:

- thermometers

3. **Cleaning -** Keep glassware clean.

a. Clean immediately after use. The longer glassware sits, the harder it is to clean.

b. Use the appropriate detergents provided or recommended by the school system for cleaning glassware. Chromic Acid (dichromate/sulfuric acid mixture) should never be used to clean glassware.

c. Be sure to rinse glassware well.

d. When using brushes, make sure the metal part of the brush does not scratch the glass.

4. **General Cautions**

a. Use glassware that is without defects and has smooth edges.

b. Glassware should have no cracks, chips, or scratches. In particular, be wary of “star cracks” that can form on the bottom of beakers and flasks. Any glassware with such cracks should be properly disposed of immediately.

c. All glass tubing used in the classroom should be fire polished. Never use glass tubing with rough or jagged ends.

d. Never set hot glassware on cold surfaces or in any way change its temperature suddenly. Even a Pyrex® or Kimax® beaker will break if cold water is poured into a hot beaker.

5. **Stuck Glassware -** Be careful with glassware that is stuck together. Only teachers, wearing goggles and gloves, should try to release the stuck glassware. If this fails, discard the glassware. Some common cases of glassware getting stuck together are:

a. nested beakers that have been jammed together;

b. stoppers that cannot be removed from bottles; and

c. stopcocks that cannot be moved.

6. **Hot Glassware**

    a. Use care when working with hot glassware. Hot glassware looks exactly the same as room temperature glassware.

    b. Do not leave hot glassware unattended and allow ample time for the glass to cool before touching.

    c. Check the temperature of the glassware by placing your hand near, but not touching, the potentially hot glass.

    d. Have hot pads, thick gloves, or beaker tongs available for grasping hot glassware.

7. **Glass Tubing -** Use caution when inserting and removing glass tubing from rubber stoppers. Lubricate glassware (tubing, thermometers, etc.) before attempting to insert it in a stopper. Protect your hands with towels or gloves when inserting glass tubing into, or removing it from, a rubber stopper. If a piece of glassware becomes stuck in a stopper, only the teacher should attempt to remove it.

    a. Breaking. Use gloves or towels to protect your hands when breaking glass tubing. Use goggles to protect the eyes. Here are the steps for properly breaking glass tubing.

        i. Scratch the glass once with a file or score.

        ii. Wrap the glass in a towel.

        iii. Place the thumbs together opposite the scratch.

        iv. Pull and bend in one quick motion.

        v. Fire polish the broken ends: hold the glass so that the sharp end is in the top of the flame of a gas burner. Rotate the tube so all sides are heated evenly, causing the sharp edges to melt, and become smooth. Place the glass on insulating material to cool.

    b. Bending. Bending glass tubing is often necessary. Follow these procedures:

        i. Place a wing-top attachment on a gas burner and heat the area of the glass to be bent while holding it with one hand on each end, rotating to ensure even heating.

        ii. When the glass is soft and pliable, remove it from the flame and quickly bend to the desired shape. Results will improve with practice.

        iii. Place on insulating material until cool.

8. **Disposal -** Defective glassware should be disposed of correctly.

a. Glassware should be disposed of in a separate container from normal trash. Such containers should be clearly labeled BROKEN GLASSWARE ONLY.

b. When handling broken glassware, wear gloves or use a dustpan and broom. Do not pick up broken glass with bare hands.

B. CORK AND STOPPERS

1. Proper Stoppers

a. Use corks for sealing organic solvents.

b. Use rubber stoppers for sealing aqueous solutions.

2. Inserting Thermometers and Glass Tubing - Use caution when inserting glass tubing or thermometers into rubber stoppers.

a. Check that the hole is the correct size.

b. Protect your hands with leather gloves.

c. Lubricate the hole with glycerin or soapy water before inserting thermometers or glass tubing.

d. During the insertion process, keep a short distance between the stopper and the hand holding the glass.

e. Use a rotary motion to guide the glass through the stopper.

f. Remove thermometers immediately after use. If they are difficult to remove, carefully cut away the cork or stopper.

C. THERMOMETERS

1. Glass Thermometers

Glass thermometers being used in the classroom must be alcohol filled. Md. Code, Environment §6-906 prohibits the use or purchase of elemental or chemical mercury in primary or secondary classrooms, which includes mercury filled thermometers. If a mercury thermometer is located in a school, it should immediately be removed and properly disposed of by the school system.

2. Resistance Thermometers

Resistance thermometers, or temperature probes, should be considered as alternatives to glass thermometers.

3. Rules for Using Thermometers

a. Never use a thermometer as a stirring device.

b. Never swing or shake down a thermometer.

c. Never use an open flame on a thermometer bulb.

d. Use extreme care when inserting or removing a thermometer from a rubber stopper.

e. Do not place thermometers where they are likely to roll or be knocked off a table. All thermometers should have anti-roll devices.

f. Make sure you choose a thermometer with an appropriate temperature range. Overheating a thermometer can cause breakage of its reservoir.

D. HEAT SOURCES

Where possible, use electric hot plates in place of gas burners (Bunsen, portable propane, and butane). *Alcohol burners should never be used as a heat source*.

1. Safety Rules for Using Electric Hot Plates

a. Use a hot plate with a smooth, clean, dry surface.

b. Make sure the hot plate is plugged into a GFI-protected outlet.

c. Only use hot plates with grounded or three-prong plugs with an Underwriters Laboratories listing.

d. Hot plates appear exactly the same whether hot or at room temperature. Always assume they are hot and act accordingly.

e. Keep the electrical cord of a hot plate away from water and the heating surface.

f. The cord of the hot plate should be checked periodically for frays and faults. Hot plates with faulty wiring should not be used. It should be repaired or replaced immediately.

g. Unplug the hot plate when finished working.

2. Safety Rules for Using Gas Burners

a. Only use gas burners in well-ventilated areas.

b. Know the location of the master gas shut-off valve. Make sure it is operational before using the gas.

c. Use only the appropriate burner type for the gas source—e.g., natural gas versus bottled gas.

d. Make sure all students know how to operate the burner safely.

e. Inspect the burner and hose for any defects.

f. Use only burner tubing connectors that meet the American Gas Association standards. Do not use latex tubing!

g. Keep rubber hoses away from the flame.

h. Use a ceramic-centered (not asbestos-centered) wire gauze under the object to be heated to distribute the heat evenly.

i. Use matches or safety lighters instead of strikers for lighting burners. Light matches or safety lighter before turning on the gas. Carefully bring flame up the side toward the top of the barrel while slowly turning on the gas.

j. Turn off the gas if the gas “flashes back” or burns at the burner base.

k. Adjust the flame to the appropriate height and color—i.e., a medium blue flame.

l. Never lean toward or reach across a flame.

m. Remember that the gas burner barrel remains hot long after use.

n. If wing tops (flame spreaders) are used, allow time for these to cool before removing them from the gas burner.

o. Never leave the flame unattended.

p. Turn off gas valves before leaving work area.

q. Do not heat organic, flammable liquids such as alcohol with active flames. Gas burners should be used primarily for heating nonflammable solvents such as water or aqueous salt solutions.

3. Safety Rules for All Heating Processes

a. Always wear goggles when heating any solid or liquid.

b. Never leave anything unattended while it is being heated or is reacting rapidly.

c. Never heat a closed container.

d. Never point the open end of a test tube toward anyone.

e. Never look into the open end of a heated test tube.

f. Test tubes should be held with a test tube holder and heated gently along the side, not at the bottom, to minimize superheating.

g. Any lab set-up should be designed to allow for fast removal of the heat source.

h. Do not clamp test tubes or flasks more tightly than necessary to hold them in place when heating. Expanding glass may break if clamped too tightly.

E. REFRIGERATORS AND FREEZERS

Refrigerators or freezers used to store chemicals and/or biological materials must be posted to warn people of the presence of these materials and to prohibit the storage of food and flammable materials.

F. ELECTRICAL HAZARDS

1. Treat all circuits as though they were energized.
2. Make sure the power is off when connections are made.
3. All electrical equipment should be grounded through three-prong plugs.
4. Use ground fault circuit interrupters (GFCIs) throughout all laboratories.
5. Test all electrical receptacles and emergency cutoff switches annually for correct wiring and functioning.
6. Test all electrical apparatus annually for voltage leaks.
7. Inspect all electrical cords annually for defects and damage.
8. Keep work areas dry when working with electrical apparatus.

G. PIPETS

Pipets are useful for measuring and dispensing liquids. The following rules apply to all types of pipets, including volumetric pipets, graduated pipets, Pasteur pipets, micro-pipets, and automatic dispensing pipets.

1. Never put a pipet in your mouth.
2. Draw the liquid into the pipet using a rubber bulb or pipet pump.
3. Never withdraw liquid from a near-empty container. If you attempt to fill a pipet under conditions where air can enter the pipet, the liquid will shoot up into the bulb or pump.
4. Never lay a pipet flat on a table or turn it upside down with the bulb or pump attached. The liquid will flow into the bulb/pump, contaminating the bulb/pump.
5. Dispose of broken pipets in the appropriate glass-disposal container.

H. VACUUMS

Vacuums occur in the laboratory usually in two situations: using a vacuum pump or by condensing vapors in a closed system (e.g., “crushed soda can” demonstration).

1. Place guards around glass containers in which a vacuum might be created.
2. Always design a relief device such as a stopcock into any vacuum system. The device should allow the slow infusion of air into a system under vacuum.

3. Avoid reactions or procedures in completely closed systems.
4. Any glassware that will be subjected to a vacuum should be specifically designed with heavy walls.
5. Properly handle and maintain vacuum pumps:
    a. change the oil on a regular basis;
    b. always have a trap attached; and
    c. have belt guards around belts and pulleys.

I. CENTRIFUGES (MACRO AND MICRO)

The centrifuge should always be securely anchored by use of suction cups or wheel brakes. The centrifuge should have a safety shield and a top disconnect switch.

Other safety procedures include the following:

1. Inspect glass tubes for cracks.
2. Inspect the metal centrifuge cups for roughness.
3. Position test tubes opposite each other with the same weight in each tube to balance the centrifuge. Use water-filled tubes as necessary for balance. An unbalanced centrifuge can “walk” off the table.
4. If the centrifuge has a lid, make sure it is closed during operation.
5. Keep hair, loose clothing, and body parts away from the centrifuge while it is operating.
6. A spinning centrifuge should not be touched for any reason. Do not try to stop a centrifuge by grabbing it. Make sure the centrifuge is completely stopped before removing test tubes from it. Note: Schools should only purchase centrifuges equipped with a safety feature that does not allow the devices to be opened until the spinning has stopped.
7. Make sure that the centrifuge operates vibration-free at top speed.
8. Never leave a running centrifuge unattended.
9. Keep rotors and buckets clean.

J. CRYOGENICS

Nonflammable cryogenics (e.g., liquid nitrogen and dry ice) can be educational but are dangerous and should be handled only by the teacher. Liquid nitrogen requires special ventable flasks or Dewars (to minimize risk of an explosion). Such flasks can break easily if handled carelessly. Use chemical splash safety goggles at a minimum (complete face shield is better), thick gloves and long sleeves when working with either of these substances. It is important that students observing demonstrations wear eye protection and be seated at a safe distance from the demonstration.

See Chapter 11.D, Heat and Cryogenic Hazards for more information.

K. COMPRESSED GASES

Compressed gases can present dangers through toxicity, reactivity, or flammability of the gas, or because the gas is pressurized. Even a normally “safe” gas, such as nitrogen, can become a safety hazard when compressed. An improperly used gas cylinder is a potential bullet or rocket. (OSHA Regulations: 29 CFR 1910.101)

1. Make sure the contents of the compressed gas cylinder are clearly stenciled or stamped on the cylinder or on a durable label.
2. Never use cylinders with missing or unreadable labels.
3. Check all cylinders for damage before use.
4. Be familiar with the properties and hazards of the gas in the cylinder before using.
5. Wear appropriate protective eyewear when handling or using compressed gases.
6. Use the proper tank and fittings/regulators designed for each gas. Your gas supplier will be able to help you with this.
7. Asphyxiation is the most subtle danger of working with compressed gases. Always use compressed gases in a well-ventilated area.
8. Check for leaks around the valve and handle using a soap solution, “snoop” liquid, or an electronic leak detector.
9. Close valves and relieve pressure on cylinder regulators when cylinders are not in use.
10. Label empty cylinders “EMPTY” or “MT” and date the tag; treat the cylinders in the same manner that you would if they were full.
11. Store empty cylinders separately from full cylinders.
12. Always make sure tanks are secure. No compressed gas tank should be allowed to stand free. All tanks should be strapped or tightly chained to a rigid support to prevent accidental toppling.
13. Have proper carts with safety chains available for transporting gas cylinders. Do not roll large cylinders around.
14. Always attach valve safety caps when storing or moving cylinders.
15. Keep electrical lines away from compressed gas tanks.

16. Do not subject any part of a cylinder to a temperature higher than 125 °F or below 50 °F.

L. COMPUTERS

The use of computers in the science laboratory has increased with the increased use of computers in student learning in schools. Although the programming and use of software with computers is not hazardous, many applications that require electrical connections to the computer may involve the risk of electrical shock. Below are guidelines for working with computers in the laboratory.

1. Place computers in the laboratory near an outlet to avoid trailing wires across the floor.
2. Make sure computers and their components are plugged into a GFI-protected outlet.
3. Extension cords are not allowed in the laboratory for permanent use. The only exception is electrical power surge protectors (UL listed) are allowed for computers and their components.
4. Keep computers and laptops away from sinks or other sources of liquids.
5. Keep computers and laptops away from heat sources, like hot plates or Bunsen burners.
6. Whenever possible, students should only make connections to external connection ports.
7. When the internal electronics must be exposed to make connections, unplug the computer.
8. Some computer applications require the use of 110-volt relays, heaters, etc., and all normal precautions for use of these devices should be followed. Be aware that the computer may remotely turn these devices on unexpectedly.

M. SHARPS

Care should always be taken when dealing with sharp objects. Scissors, needle probes, and knives should be used with extreme care. Sharps to be discarded – and any other items having sharp edges or points – should be placed in a separate, rigid container labeled SHARPS ONLY.

N. OTHER GENERAL LABORATORY SAFETY CONCERNS

1. Always keep your workspace free of clutter.
2. Apparatus attached to a ring stand should be positioned so that the center of gravity of the system is over the base and not to one side.
3. Apparatus, equipment, or chemical bottles should not be placed on the floor.
4. Whenever hazardous gases or fumes are likely to be involved, the operation should be confined to a fume hood.
5. Any problems with glassware, equipment, chemicals, etc. should always be reported immediately to the instructor.

6. High/low pressure situations (e.g., pressurized systems for specialized reactions, or vacuums) can present hazards. Only sound glassware should be subjected to such situations.

See Chapter 3, Safety Concerns and Safety Equipment, and Chapter 5, Safety Strategies in the Classroom, for related ideas on safety practices.

Chapter 7: Chemical Management, Handling, and Disposal

Maintaining chemical safety requires care in ordering, storing, using, and disposing of chemicals. Chemical safety is the responsibility of many individuals throughout the school system and in the school. Safe management of chemicals in the classroom requires that the teacher have adequate knowledge of the chemicals to be used and their interactions.

A. CHEMICAL HYGIENE PLAN

In 1990, the Occupational Safety and Health Administration (OSHA) instituted “The Laboratory Standard”—Occupational Exposure to Hazardous Chemicals in Laboratories (29 CFR 1910.1450). Thi “Laboratory Standard” has been designed to address the specific safety needs of the laboratory.

The Laboratory Standard ensures that employees who work in a laboratory setting will be protected from any chemical exposure that exceeds permissible exposure limits and that employees will be educated as to the hazardous nature of the chemicals they use in the laboratory. To achieve this goal, the Laboratory Standard requires the school systems to appoint a chemical hygiene officer to develop, implement, and monitor a chemical hygiene plan (CHP). Each school in the school system might also need to develop its own CHP and identify a chemical hygiene officer for that building. The chemicals involved in the CHP go beyond just those found in the science laboratory and include other chemicals in the building like art supplies, cleaning supplies, and materials used in completer or CTE programs.

A basic CHP for a school should include the following information:

1. Standard operating procedures relevant to safety and health considerations to be followed when laboratory work involves the use of hazardous chemicals;

2. Before a chemical is procured, proper handling, storage and disposal methods must be known to those responsible;

3. Criteria that the employer will use to determine, and implement control measures to reduce employee exposure to hazardous chemicals including engineering controls, the use of personal protective equipment and hygiene practices;

4. Designation of personnel responsible for implementation of the Chemical Hygiene Plan including the assignment of a Chemical Hygiene Officer, and, if appropriate, establishment of a Chemical Hygiene Committee;

5. Circumstances under which a particular laboratory operation, procedure or activity shall require prior approval from the employer or the employer's designee before implementation;

6. Provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work area; and

7. Procedures for employees who work with hazardous chemicals to receive medical attention under specified circumstances.

See Appendix B: Chemical Hygiene Plan (CHP) for more information.

B. MANAGING CHEMICALS

1. Selecting Chemicals

When using chemicals in the classroom, the educational benefit of specific chemicals needs to be weighed against the potential risks and disposal of that chemical. Each school system should develop and distribute guidance on the chemicals acceptable for use in the various science courses. A teacher who wishes to use a substance not on the appropriate list must seek the permission of the science supervisor by submitting a written request. The request should include the following:

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

b. Information supporting the following assertions:

   i. Use of the substance is pedagogically sound.

   ii. The demonstration or laboratory exercise using the substance is an effective way to illustrate an important property, process, or concept.

   iii. No satisfactory substitute for the substance is readily available.

   iv. Adequate safeguards are in place to ensure proper use of the substance.

   v. Students will be instructed in the proper handling of the substance (as indicated in the lesson plan).

c. The following information to enable the supervisor to make an informed decision:

   i. The extent of exposure of students and the teacher to the chemical (including estimate of time to the nearest minute).

   ii. The age or maturity level of the students who will be exposed.

   iii. The recommended maximum levels of exposure set by regulatory and/or professional organizations.

d. In considering a substance for use in the laboratory, teachers are advised to check the Safety Data Sheets (SDSs) for each chemical, in chemical catalogs, and on container labels. Most chemical's SDS can be found on the Internet. Carcinogens, teratogens, mutagens, heavy metals, explosives, and highly flammable chemicals should never be brought into the school science laboratory. Resources available to identify hazardous chemicals also include the following:

i. The Centers for Disease Control and Prevention (CDC) Occupational Cancer – Carcinogen List.

ii. The National Toxicology Program's Report on Carcinogens.

iii. The National Research Council's Prudent Practices in the Laboratory, Updated Version (2011), Chapter 4.

iv. The Teratogen Information System (TERIS).

v. The District of Columbia Public Schools Prohibited and Restricted Chemical List.

2. Chemical Inventory

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

The chemical inventory record should:

- contain the date the inventory was conducted.
- identify chemicals by name and formula.
- specify the amount of each chemical present.
- indicate the storage location of each chemical.
- indicate the hazard of each chemical, using information from the Safety Data Sheet (SDS) for each substance and the appropriate National Fire Protection Association hazard code. See Appendix E, NFPA Identification Codes, and Appendix C, Hazard Communications Standard.
- indicate the arrival date and quantity of all chemicals received.
- maintain a complete inventory in a separate location than the room where the chemicals are stored so a copy is available to fire fighters or in case of emergency.

3. Ordering Chemicals

a. Before ordering chemicals, the person responsible should:

i. make sure the chemical is on the school system's list of approved chemicals.

ii. be capable of assessing the hazards of the chemical.

iii. check the chemical inventory to make sure the chemical is not already in the building.

iv. be sufficiently knowledgeable to recognize requests from teachers for nonessential chemicals.

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

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

d. For each chemical ordered, ask the following questions:

i. Can proper storage be provided for the chemical?

ii. Are the facilities appropriate for the use of the chemical?

iii. Will the chemical or its end products require disposal as hazardous waste?

iv. Is appropriate personal protective equipment available for safe use of the chemical or its end product?

v. Have people who will handle and use the chemical been trained in handling chemicals? Are they aware of the hazards?

4. Chemical Storage

a. General Guidelines

i. Secure storage areas against unauthorized removal of chemicals by students or others.

ii. Protect the school environment by restricting emissions from stored chemicals. Vents should be ducted to the outside.

iii. Maintain clear access to and from the storage areas.

iv. Do not store chemicals in aisles or stairwells, on desks or laboratory benches, on floors or in hallways, or in fume hoods.

v. Use NFPA- or OSHA-approved storage cabinets for flammable chemicals.

vi. Use an appropriate "Acid Cabinet" for any acid solutions of 6 M concentration or higher. Nitric acid needs to be isolated.

vii. Do not use standard refrigerators to store flammable chemicals. If storying flammable materials, use refrigerators of explosion-proof or explosion-safe design only. Place NO FOOD labels on all refrigerators used to store chemicals.

viii. Label storage areas with a general hazard symbol to identify hazardous chemicals and indicate correct firefighting procedures. See Appendix E, NFPA Identification Codes.

ix. File a Safety Data Sheet (SDS) for every chemical stored in the laboratory.

x. Store all chemicals in compatible family groups. Do not alphabetize. See Appendix F, Storage of Chemicals.

xi. Store all chemicals at eye level and below. The preferred shelving material is wood treated with polyurethane or a similar impervious material. All shelves should have a two-inch lip. If you use shelving with metal brackets, inspect the clips and brackets annually for corrosion and replace as needed.

xii. Store chemicals prepared in the laboratory in plastic bottles (if possible and appropriate to the chemical) to minimize the risk of breakage.

xiii. Date containers upon receipt and again when opened.

xiv. Attach chemical labels with all necessary information to all containers. See Chapter 7.B, Managing Chemicals.

xv. When opening newly received chemicals, immediately read the warning labels to be aware of any special storage precautions such as refrigeration or inert atmosphere storage.

xvi. Test peroxide-forming substances periodically for peroxide levels; dispose of these substances after three months unless the SDS for the substance indicates a longer shelf life. See Appendix G, Hazards of Peroxide-Forming Substances, and Appendix C, Hazard Communications Standard.

xvii. Check chemical containers periodically for rust, corrosion, and leakage.

xviii. Store bottles of especially hazardous and moisture-absorbing chemicals in chemical-safe bags.

xix. Maintain a complete inventory in the room where the chemicals are stored and make a copy available to fire fighters.

xx. Keep storage areas clean and orderly at all times.

xxi. Have spill cleanup supplies (absorbents, neutralizers) in any room where chemicals are stored or used.

b. Storage of Flammable and Combustible Liquids

i. Definitions:

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

2. Flammable liquid is defined as any liquid that has a flash point below 100 EF (37.8 EC).

3. Combustible liquid is defined as any liquid that has a flash point at or above 100 EF (37.8 EC).

ii. Guidelines:

1. Limit the amount of flammable and combustible materials stored to that required for one year of laboratory work.

2. Use only NFPA- or OSHA-approved metal flammables cabinets to store flammable and combustible liquids. Label the cabinets FLAMMABLE - KEEP AWAY FROM FIRE.

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

c. Storage of Compressed Gases

i. Use small lecture-bottle-type gas cylinders only. Store all gas cylinders in an upright position.

ii. Store gas cylinders in a cool dry place away from corrosive chemicals or fumes.

iii. Store gas cylinders away from highly flammable substances.

iv. When cylinders are no longer in use, shut the valves, relieve the pressure in the gas regulators, remove the regulators, and cap the cylinders.

v. Label empty gas cylinders EMPTY or MT.

vi. Store empty gas cylinders separately from full gas cylinders.

vii. Store flammable or toxic gases at or above ground level–not in basements.

viii. Use cylinders of toxic, flammable, or reactive gases in fume hoods only.

ix. When moving cylinders, be sure the valve cap is securely in place to protect the valve stem and valve. Do not use the valve cap as a lifting lug.

x. If large gas cylinders are used, they should be chained. A hand truck should be available for transporting them to and from the storage area.

5. Labeling of Stored Chemicals

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

a. Purchased Chemicals - All purchased chemicals should be labeled with:

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

b. Solutions - All solutions created in the laboratory should be labeled with:

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

C. HANDLING CHEMICALS

1. Dispensing Chemicals

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

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

a. Safety Guidelines for Dispensing Chemicals

- Use the smallest amount of the chemical possible in any experiment. Microscale experiments should be considered.
- Consider distributing the amount of chemical for an experiment into vials for each student. This minimizes waste and can save time during the class period.

- Use proper containers for dispensing solids and liquids. Solids should be contained in wide-mouthed bottles and liquids in containers that have drip-proof lips.
- Label all containers properly.
- Never return dispensed chemicals to stock bottles, as it inevitably results in contamination despite your best precautions.

b. Dispensing Flammable Liquids

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

Such containers should be bonded and grounded:

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

2. Common Hazards

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

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

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

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

- Flash point is the minimum temperature of a liquid at which sufficient vapor is given off to form an ignitable mixture with air.
- Ignition temperature is the minimum temperature required to initiate self-sustained combustion independent of a heat source. See Chapter 7.B, Managing Chemicals.

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

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

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

d. Toxins - A toxic substance is one that, even in lesser amounts, can injure living tissue.

   i. Methods of Toxins Entering the Body:

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

      2. *Absorption* - Absorption through the skin often causes dermatitis. Some toxins that are absorbed through the skin or eyes can damage the liver, kidney, or other organs.

      3. *Inhalation* - Absorption through the respiratory tract (lungs) through breathing. This process is the most important route in terms of severity.

      4. *Injection* - Percutaneous injection of a toxic substance through the skin. This process can occur in the handling of sharp-edged pieces of broken glass apparatus and through misuse of sharp materials such as hypodermic needles.

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

      1. *Irritants* are noncorrosive chemicals that cause reversible inflammatory effects (swelling and redness) on living tissue by chemical action at the site of contact. Because a wide variety of organic and inorganic

chemicals are irritants, skin, and eye contact with all chemicals in the laboratory should be avoided.

2. *Corrosive substances* are solids, liquids, and gases that destroy living tissue by chemical action at the site of contact.

3. *Allergens* are substances that cause an adverse reaction by the immune system. As these reactions result from previous sensitization from the substance or similar substance, chemical allergens will be different for each person.

4. *Asphyxiants* are substances that interfere with the transport of an adequate supply of oxygen to the vital organs of the body. They can do this by either displacing oxygen from the air or by combining it with hemoglobin and thus reducing the blood's ability to transport oxygen.

5. *Carcinogens* are cancer-causing substances listed in the *Report on Carcinogens*. Many substances known or suspected to be carcinogenic are still found to be in high school laboratories. There is little reason for most of them to be there; they should be disposed of as quickly as possible.

6. *Reproductive & developmental toxins* (teratogens and mutagens) either have an adverse effect on the various aspects of reproduction (fertility, gestation, lactation, and general reproductive performance) or act during pregnancy to cause adverse effects on the embryo or fetus.

7. *Neurotoxins* induce an adverse effect on the structure or function of the central and/or peripheral nervous system. These effects can be permanent or reversible.

8. *Toxins* affecting other organs can also be a hazard. Most of the chlorinated hydrocarbons and aromatic compounds, some metals, carbon monoxide, cyanides, and others can produce one or more effects on target organs in the body.

e. Mercury

Md. Code, Environment §6-906 prohibits the use or purchase of elemental or chemical mercury in primary or secondary classrooms. Any mercury or devices containing mercury found in a school should be removed by a certified hazardous waste disposal company. Each school system should have a contract with a company able to remove and dispose of the mercury. These rules stem from the fact that mercury and its compounds, both organic and inorganic, are health hazards. Metallic mercury has a measurable vapor pressure, and the production of vapor is accentuated by heating the mercury or subdividing as occurs in a spill. Laboratory sources of mercury include, among others, thermometers, manometers (barometers), and batteries. Not only is the vapor harmful, but the metal itself is absorbable through the intact skin.

3. **Spill Cleanup**
   a. General Notes on Chemical Spills
      i. Spills should be contained, the area cleared of students, and the spill cleaned up immediately.
      ii. Waste from spill cleanup should be disposed of appropriately. See Chapter 7.D, Chemical Waste Strategies.
      iii. After the floor spill has been thoroughly cleaned up in the appropriate manner, the area should be mopped dry to minimize the risk of slipping and falling.
   b. Spills that Constitute Fire Hazards
      i. Extinguish all flames immediately.
      ii. Shut down all experiments.
      iii. Vacate the room until the situation has been corrected.
   c. Other Spills
      i. Use an absorbent material to neutralize the liquids. Materials include:
         1. for acids, powdered sodium bicarbonate
         2. for bromine, sodium thiosulfate solution (5-10%) or limewater
         3. for organic acids, halides, nonmetallic compounds, or inorganic acids, use slaked lime and soda ash
         4. or general spills, use commercial absorbents or spill kits, small particles of clay absorbents (kitty litter), or vermiculite
      ii. Wear rubber gloves and use a dustpan and brush. Clean the area thoroughly with soap and water, then mop dry.
      iii. Aromatic amine, carbon disulfide, ether, nitrile, nitro compound, and organic halide spills should be absorbed with cloths, paper towels, or vermiculite and disposed of in suitably closed containers.

4. **Mercury Spills**

Md. Code, Environment §6-906 prohibits the use or purchase of elemental or chemical mercury in primary or secondary classrooms. If mercury from a device such as an old thermometer spills mercury in a school setting follow these procedures, or the designated procedures of the local school system.

1. Have everyone, especially students leave the area; do not let anyone walk through the mercury on their way out.
2. Open all windows and doors to the outside, if possible.
3. Close all doors to other parts of the school.
4. Notify the school administrator or building supervisor. They will determine the next steps for cleaning up the spill.

Do not attempt to clean up the spill unless directed to do so by the school administrator or building supervisor. Guidance for cleaning up small mercury spills can be found on the EPA website.

D. CHEMICAL WASTE STRATEGIES

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

1. Minimizing Waste

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

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

Toxic Chemical	Substitute
Trisodium phosphate	Ordinary detergents
Alcoholic potassium hydroxide	Ordinary detergents

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

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

d. Coordinate Laboratory Work - When planning laboratory experiments, try to coordinate with coworkers who may be doing the same or similar experiments so that solutions or reagents are made up at one time in the building, thus minimizing the amount of “left-over” chemicals at the end of the experiment.

e. Group or Station Work - Have certain groups of students perform components of the lab to reduce waste. All students may not necessarily have to conduct all components or variations of the experiment. Separate groups perform variations and then the data is shared with the larger group or class, so all students have the final data without modifying all the various variables in the experiment.

2. Waste Storage Prior to Disposal

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

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

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

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

3. Disposing of Waste

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

a. Classification of Hazardous Waste

The Environmental Protection Agency classifies wastes as:

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

b. Classroom Management

- Make disposal options a part of all laboratory instructions for students. For each chemical waste produced, instruct students as to the appropriate disposal, including disposing of the substance in a disposal container or down the drain. See Drain Disposal in the next bullet.
- Place all laboratory waste in a properly labeled container. The label should contain the date and type of waste.
- Immediately following the laboratory activity, place the waste containers in a secure location until the containers can be removed to the central storage area.
- Some chemical waste may be recycled. Teachers should seek guidance on recycling from local safety officers or other knowledgeable administrative staff.

c. Drain Disposal

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

Positive Ions	Negative Ions
aluminum	borate
ammonium	bromide
bismuth	carbonate
calcium	chloride
copper	cyanate
hydrogen	hydrogen sulfide
iron	hydroxide
lithium	iodide
magnesium	nitrate
potassium	phosphate
sodium	sulfate
strontium	sulfite
tin	tetraborate
titanium	thiocyanate
zinc	None
zirconium	

- The following organic compounds may be able go into a drain if allowable by the local wastewater treatment plant authority:
  - acetic acid
  - oxalic acid
  - acetone
  - pentanols
  - butanols
  - propanols

- esters with less than 5 carbon atoms
- sodium salts of carboxylic acids
- ethanol potassium salts of carboxylic acids
- ethylene glycol formic acid
- glycerol sugars
- methanol

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

d. Compounds Not Suitable for Drain Disposal

For compounds not suitable for drain disposal, label, and follow local school system procedures for the disposal of hazardous waste via its contracted hazardous waste disposal vendor. Even with the disposal of hazardous waste by licensed and approved firms, generators of hazardous waste are responsible for the waste.

Chapter 8: Outdoor and Field Studies Safety

Taking students outdoors and on field studies can be a valuable, positive addition to the science program, especially in an environmental curriculum or with an environmental literacy related learning experience. Effective outdoor activities or field study are most valuable when educational objectives are clearly identified, and the experiences are constructed or designed to achieve those objectives. When the activity is well planned and organized, the possibility of accidents occurring is reduced. Thorough preparation can ensure safety for all participants.

A. PREPARATION

1. Permissions and Notifications

a. Obtain the principal's approval and inform other staff of the date and destination of the trip.

b. Obtain parents' or guardians' permission for their student to participate in studies off the school grounds. Have students take a written description of the trip home to their parents or guardians. Include in the information the types of clothing to be worn, safety precautions to be taken, and a permission form. Provide the information and permission slip in the student's native language if possible for those parents or guardians who need it.

c. On the day of the outdoor activity or field study, post on the classroom/laboratory door or other conspicuous location a sign indicating the destination of the class trip and departure and return times.

2. Participation

a. Determine the appropriateness of the outdoor activity or field study for all students based on any physical disabilities or impairments, allergies, or other conditions that could impair or limit their participation.

b. Compile a list of all students participating in the trip and provide a copy to the school office.

3. Arrangements

a. When planning an off-site trip, consider the accommodations outlined in your students' IEP and 504 plans and ensure that the trip being planned is accessible to all students. It may be appropriate to coordinate with your special education administrator or IEP chair if there is a need for additional support to ensure student access, such as specialized transportation equipment, Augmentative and Alternative Communication (AAC) devices, or additional staff.

b. If students have a health plan, consult with the school nurse to ensure that all support outlined in that plan is accessible to the student for the duration of the trip, as appropriate.

c. Arrange for transportation to the site using transportation approved by the local school system.

d. When planning a trip to a facility such as a factory or laboratory, arrange for an experienced facility representative to conduct the tour. The visit should be well supervised.

e. Arrange for parents/guardians or other responsible adults to assist with supervision as required by school system policies.

4. Rules

a. Follow the rules your school or school system has established relating to trips outside the school. Make sure students know that regular school rules apply during outdoor activities and field study off campus.

b. Before each trip, establish any additional rules for safe student conduct and explain the rules to all participating students and adult supervisors.

c. If the outdoor activity or field study requires students to be on or in water, make sure to follow all school system policies or rules. School systems may have specific requirements related to the types of boats and certifications that teachers must have to take students on the water.

5. Site Survey

Visit the site prior to the trip and conduct a survey of the area. The survey should include identification of any of the following conditions or potential dangers that need to be addressed in planning the trip:

a. Conditions that could cause students to fall, such as steep terrain, slippery or unstable rocks, or animal burrows or holes.

b. Unstable objects overhead that may fall.

c. Foot bridges or other crossings which may collapse under student weight.

d. Deep water or currents strong enough to sweep students off balance.

e. Animals capable of injuring students, including poisonous or venomous animals, ticks, or mites.

f. Potentially allergic substances or poisonous plants.

g. Vehicle traffic.

h. Seasonal hunting areas.

i. Electrical hazards.

j. Threatened and endangered species.

k. Areas that have been sprayed with herbicides or pesticides.

l. Ensure that the site is accessible for all students.

6. Precautions and Emergencies

Before the outdoor activity or field study, some precautionary measures should be taken to ensure a safe trip.

a. Based on the pre-trip survey, map the safest passage through the area.

b. Instruct the students in:

    i. safe methods of movement through the study area, with special caution given to the transport of equipment.

    ii. recognition and avoidance of poisonous plants and animals.

    iii. the need for and use of appropriate shoes and other clothing.

    iv. safe methods for working on or near bodies of water (including the appropriate use of the buddy system and life jackets). Do not assume all students know how to swim. Basic water safety rules may be found at the American Red Cross and other similar websites.

    v. the proper use of equipment, including the use of chemical splash safety goggles (or other eye protective devices).

    vi. proper use and handling of chemicals used for water and soil testing.

c. Prepare for emergencies in the following ways:

    i. Determine a method for contacting the school office in case of an emergency.

    ii. Be prepared to follow the school or school system's emergency procedures in the event of an accident.

    iii. Maintain up-to-date medical information and emergency telephone numbers for each student.

    iv. Be aware of any medication students are currently taking and determine if the medications will need to be taken while on the trip.

    v. Be sure that first-aid kits are readily available and check the kits to make sure they contain the essential items.

vi. Identify procedures for the immediate, on-site treatment for insect or animal bites, accidental ingestion of poisonous plant matter, or other medical emergencies until professional medical treatment is obtained.

vii. Be prepared to provide appropriate means for transporting an injured student to receive treatment.

B. AT THE SITE

1. Monitor students to ensure that they are adhering to the precautions and rules developed in planning the trip.

2. Specific considerations for safety at the site include the following:

   a. Goggles

      i. Require students to wear chemical splash safety goggles whenever they use laboratory chemicals or solutions. Students should wear impact goggles when using sharp objects such as chipping hammers or picks. All persons in close proximity to such activities must also wear goggles.

      ii. If students share goggles, the goggles must be cleaned and disinfected after each use. See Chapter 4.A, Eye Protection.

   b. Collecting Organisms

      i. Field study should not include the removal of organisms unless a valid educational purpose is served by the removal and adequate research has been done to ensure both the safety and legality of the removal. See Chapter 9, Life Science.

      ii. The collection of organisms for counting or classification should be done in a way to ensure that the organisms will have the greatest chance of survival when released back into the environment.

   c. Containers

      Use plastic, paper, or cloth containers to prevent cuts and loss of specimens due to breakage. Avoid glass collection jars or containers where possible.

Chapter 9: Life Science

Life science (Biology and Environmental Science) teachers and their students face a wide range of potential hazards. In addition to chemicals, there are hazards associated with the handling of organisms, classroom activities on the school grounds and outdoor study areas, and the containment of biological specimens. Effective control of such hazards involves both the recognition of each hazard and the development of control procedures.

A. PERSONAL SAFETY

Every student and teacher should be protected by safety devices when experiments are being conducted in the life science laboratory.

See Chapter 4, Personal Protective Equipment.

1. Body and Clothing Protection

See Chapter 4.C, Body Protection

2. Eye Protection

See Chapter 4.A., Eye Protection; Chapter 6.J, Cryogenics; and Chapter 8.B, At the Site.

3. Hand Protection

a. Students should use nitrile, rubber, or plastic gloves when handling preserved organisms.

b. Heavy rubber or leather gloves should be provided for use when handling live animals as a protection against animal bites and scratches.

c. Soap and water or hand sanitizer should be available for student use. Students should be required to wash their hands before and after laboratory experiments that involve the handling of live or dead organisms.

See Chapter 4.C, Body Protection.

4. Respiratory Protection

See Chapter 3.E, Ventilation, and Chapter 4.C, Body Protection.

B. CLASSROOM/LABORATORY SAFETY

1. Equipment

See Chapter 6, Safe Handling of Equipment.

2. Chemicals

a. Stains

Teachers must obtain the appropriate Safety Data Sheets (SDSs) for all staining chemicals and follow the stated precautions. See Appendix C, Hazard Communications Standard.

b. Drug-Related Items

The following substances commonly used in the biology program have special security needs because of their potential abuse. They should be kept in a secure area and used with caution:

- Acetaldehyde
- Histamine
- Adrenalin
- Nicotine
- Colchicine
- Testosterone
- Caffeine
- Thiourea
- Ethyl Alcohol (grain)
- Tobacco

3. Dissections

a. Students should wear chemical splash safety goggles and aprons.

b. Long hair, loose clothing, and jewelry should be secured.

c. All students should wear nitrile, rubber, or plastic gloves.

d. The room should be adequately ventilated during dissections, particularly when preserved specimens are used.

e. Care should be used in the handling of all dissection instruments.

f. Dissecting pans or trays should be provided.

g. Scalpels or single-edged razor blades should be used. Single-edge razor blades with a rigid, reinforced back are preferred.

h. Students should be instructed to cut away from the body and to cut down against the dissecting pan or tray. Care must be taken to keep the hand that is not holding the cutting instrument away from the cutting edge.

i. It is important to secure the specimen in or to the pan or tray. Dissection pans may be used. See Chapter 9.D, Zoology: Animal Considerations.

4. **Heating and Sterilization Devices**

    a. Autoclaves/Dry Heat Sterilizers/Pressure Cookers.

        i. Autoclaves and dry heat sterilizers are preferred.

        ii. Heat sterilizers are preferred over pressure cookers. A pressure cooker may be used as a substitute, but it requires greater attention due to the hazards involved in a non-automated system.

        iii. All precautions in dealing with electrical equipment should be taken.

        iv. Most plastic containers and equipment, such as plastic petri dishes, are not autoclavable.

        v. Autoclaves, heat sterilizers, and pressure cookers should be run only by the teacher or professional aide or by the student aide if they are under the direct supervision of the teacher or professional aide. The teacher, professional aide, and student aide should be knowledgeable about the operating instructions of the pressure cooker, autoclave, or heat sterilizer.

        vi. In using a pressure cooker, check the safety valve before pressure builds up. Final gauge pressure must not exceed 15 pounds per square inch. The equipment should be turned off and allowed to cool before the stopcock is opened to equalize pressure. Dry the pressure cooker before storing because aluminum will oxidize if stored wet, and pits produced from the oxidation may weaken the metal when under high pressure. See Chapter 6.F, Electrical Hazards, and Chapter 9.C, Microbiology.

    b. Gas burners. When heating materials at high temperatures, a gas burner may be used. See Chapter 6.D, Heat Sources.

    c. Hot plates. See Chapter 6.D, Heat Sources.

    d. Water baths. The baths must be well maintained for safe operation.

    e. Incubators. Care should be taken to keep incubators safe and well maintained. They should be cleaned out regularly to prevent unwanted growth of organisms. Students should be instructed on their proper use.

    f. Microwave Ovens. Microwave ovens should be safely located and appropriately maintained. Students should be instructed on their proper use.

5. **Microscope Work**

    a. Microscopes

i. Students should be instructed in the proper use of the microscope.

ii. All precautions in dealing with electrical equipment should be taken.

iii. If microscopes with reflecting mirrors are used for illumination, care must be taken to prevent using direct sunlight as the illumination source.

iv. Students with eye infections should not be allowed to contaminate the eyepiece(s) of the microscope.

b. Microtomes

i. A microtome may be a useful tool, especially in upper-level life science classes. Students must be instructed in the proper use of the microtomes, which contain extremely sharp knife blades. See Chapter 11.B, Electrical Hazards.

6. Refrigerators and Freezers

See Chapter 6.E, Refrigerators and Freezers.

C. MICROBIOLOGY

This section pertains primarily to the use of viruses, bacteria, and other microscopic organisms. Bloodborne pathogens require special consideration. The handling of these pathogens is treated in 29CFR 1910.1030. This publication covers definitions, exposure control, specific procedures, and protocols to comply with the regulations, precautions for specific pathogens, signs, labels, training, and record keeping. Proper laboratory technique is the basis for all cautions in this section. See Chapter 9.D, Zoology: Animal Considerations, and 9.F, Biotechnology and Recombinant DNA Research.

1. Materials and Specimens

a. Known pathogens should never be used in the classroom.

b. Specimens should be obtained from reliable supply companies or other sources that can validate species or strains. Most supply company catalogs indicate which organisms are pathogens and which are not.

c. Specimens should be requested for shipment when needed and not stored for extended periods of time.

d. All microorganisms should be handled as if they were pathogens.

e. Proper aseptic techniques should be used at all times when working with bacterial, viral, or microbial cultures.

f. Microorganisms cultured directly from the environment should not be incubated for cell cultures as incubation could promote the growth of pathogenic organisms.

g. Humans and/or human products should not be used as a source of bacterial/microbial culture material in most cases. In exceptional circumstances (e.g., AP Biology), teachers should obtain the school system science supervisor's permission and follow the Universal Precautions.

h. Blood agar, serum agar, and/or chocolate agar should not be used in classroom experimentation.

i. Staining chemicals may be purchased through supply companies.

See Chapter 9.B, Classroom/Laboratory Safety, and 9.F, Biotechnology and Recombinant DNA Research.

2. Equipment

Essential equipment for working with microorganisms includes:

a. Sterilization equipment (autoclave, heat sterilizer, or pressure cooker) for media preparation, sterilization of glassware and equipment, and decontamination of disposable material

b. Sterile transfer equipment (micropipetters with disposable tips or sterile pipets) for safe transfer of microorganisms

c. Adequate workspace and equipment to prepare media

d. Proper storage facilities, including refrigeration and incubation equipment

e. Supplies for cleaning up and disinfecting work areas

f. Pipets. Due to the nature of microorganisms, the use of disposable pipets, pipet tips are recommended. If you use nondisposable pipets, take care to properly decontaminate them. See Chapter 6.A, Glassware.

g. Special trash containers for all cultures for proper sterilization and disposal. There should be separate containers for the disposal of glass, plastic, paper, etc. All trash receptacles should be clearly identified.

h. Petri dishes for use with noninfectious materials

   i. Due to the nature of microorganisms, the use of disposable petri dishes and culture plates, etc. is recommended. If you use nondisposable glassware, take care to properly decontaminate it. See Chapter 6.A, Glassware.

   ii. Glass petri dishes should be sterilized before use. After use, dispose of the culture medium in a sealed container and soak the dishes in strong disinfectant. Wash them in detergent and autoclave. See the Decontamination and Disposal of Materials section below.

   iii. Use sterile plastic Petri dishes only once. After using them, tape the dishes shut, place them in a bag, and dispose of them in an incinerator or the trash according to recommended disposal guidelines.

3. **Procedures and Sterile Techniques**

   a. Keep the laboratory clean.

   b. Disinfect the work area before and after each laboratory procedure. Use of a commercial disinfectant to wipe down the area is acceptable.

   c. Students should use gloves, chemical splash safety goggles, and aprons as the teacher deems necessary.

   d. Do not leave laboratory materials unattended.

   e. Inoculating loops

      i. Inoculating loops should be flamed before and after the transfer of microorganisms and a final time before storing.

      ii. The inoculating loop should be used with a steady hand and should not be used for stirring, as splashing may occur.

      iii. When transferring the inoculant, do not use a hot loop, which can cause spattering of the culture medium and thereby create aerosols of the culture organisms. (Make sure the loop is cool by touching the loop to an area of the sterile agar that will not be used or allowing the loop to air cool for a few seconds.)

   f. When a liquid culture medium is used, the liquid should never be allowed to come in contact with the stopper used to seal the culture medium. Care should be taken to avoid spattering when the stopper is removed.

   g. Forceps should be used to handle slides, and slides should be flamed with care to avoid burns and shattered slides.

   h. Cultures should be incubated at temperatures no higher than 25E C to decrease the possible growth of pathogens.

   i. Pipetting of bacteria

      i. Use a micropipette or disposable pipet and a pipettor or pipet bulb. Micropipettes are preferred for transfers of tiny amounts of liquid inoculant. A disposable pipet is preferred for larger amounts.

      ii. Used glass pipets should be immersed in disinfectant and then autoclaved. Do not allow students to aspirate or to spray bacterial/microbial cultures, which can create a serious biological hazard. Never allow mouth pipetting.

      iii. Colonies should be counted on closed Petri dishes or plates. Parafilm is recommended for sealing culture plates.

iv. Any demonstration plates passed around the class must be sealed with parafilm or tape.

v. An autoclave, heat sterilizer, or pressure cooker should be available. See Chapter 9.B, Classroom/Laboratory Safety. See also Chapter 6.G, Pipets, and Chapter 6.I, Centrifuges.

4. Decontamination and Disposal of Materials

Disposal of scientific materials such as chemicals is an issue in every science classroom and laboratory. In biology, it is necessary to differentiate between infectious and noninfectious materials.

a. *Noninfectious materials* include materials such as chemicals, household substances, and biological samples free of parasites or contagious pathogens. These are substances that carry no "communicable" hazard.

Noninfectious biological waste should be treated with sound safety management techniques. To dispose of these materials, place them in double domestic plastic trash bags secured by metal wire twists. The bagged wastes may then be placed in domestic trash receptacles to be disposed of in an approved landfill in accordance with state and local regulations. See Chapter 7.D, Chemical Waste Strategies.

b. *Infectious materials* (or biological waste or biohazardous waste) are communicable biological materials. These materials include contagious microorganisms or parts of microorganisms (including bacteria, viruses, or DNA fragments) as well as disposable biological equipment that has been exposed to infectious materials.

Infectious biological materials require decontamination prior to disposal through one of the following methods.

i. Incineration on-site. This approach is the preferred process. This method renders the waste noninfectious and, at the same time, changes the shape and form of the waste. Schools that have incinerators must comply with all applicable environmental regulations regarding air quality and air emissions. The next method is emphasized here because most schools do not have on-site incineration.

ii. Decontamination. Infectious materials may be rendered noninfectious by decontamination (sterilization) prior to disposal. Below are the methods of decontamination most commonly practiced in high schools.

1. Steam sterilization in an autoclave at a pressure of approximately 15 psi and a temperature of 121°C (250°F) for at least 15 minutes will destroy microbial life, including high numbers of microbial spores.

2. Dry heat sterilization may be used. However, this method requires temperatures of 160-170°C (320-338°F) for 2-4 hours.

Note: In both cases, the autoclaves should be calibrated for temperature and pressure and monitored with a biological indicator, such as Bacillus stearothermophilus spores, to ensure effectiveness of the sterilization. It is important that steam and heat contact the biological agent. Therefore, bottles containing a liquid material should have loosened caps or cotton plug caps to allow for steam and heat exchange within the bottle. Biohazard bags containing waste should be tied loosely. It is recommended that bags of biohazard waste be affixed with autoclave indicator tape to ensure the temperature readings are accurate. Once disinfected, waste can be treated as noninfectious waste, double bagged in domestic plastic trash/garbage bags, and secured by metal wire-containing twist ties. Treated bags and containers may then be disposed of in an approved landfill in accordance with state and local regulations. See Chapter 6.M, Sharps.

3. If neither of these sterilization techniques is practical, the infectious waste may be transported off-site to a qualified medical waste disposal firm for subsequent treatment and disposal.

4. If none of the above procedures is possible, the infectious waste may be immersed in household bleach for 6-10 hours. Although chemical disinfection is not considered completely effective, bleach is considered effective in wiping down exposed surfaces and equipment.

D. ZOOLOGY: ANIMAL CONSIDERATIONS

1. Human

Non-invasive, non-stress laboratory activities involving students as experimental subjects are encouraged. These include physiological measurements such as pulse, blood pressure, heart rate, breathing rate, hearing, sight, etc. Every precaution must be taken to ensure student safety.

The following are examples of safety precautions that should be followed.

a. Blood Pressure. When using the sphygmomanometer to take blood pressure, do not pressurize the cuff higher than 150 mm Hg. Allow two minutes to pass before re-inflating the cuff when taking repeat blood pressure measurements on the same individual. This experiment can cause stress leading to a shock reaction and unconsciousness.

b. Respiratory Experiments. When respiratory experiments are done, remember that hyperventilation can be dangerous to anyone but particularly to asthmatics, epileptic people, and those who suffer from bronchial conditions. When the spirometer is used, a clean mouthpiece should be used by every person being tested. When testing for carbon dioxide, care must be taken not to allow the test solution (bromothymol blue and calcium hydroxide) to reach the mouth. This experiment can cause stress leading to a shock reaction and unconsciousness.

c. Stethoscope Use. Disinfect stethoscope earpieces after each use. Teach students the proper use of the stethoscope to avoid potential ear damage.

d. Body Fluids and Bloodborne Pathogens. Whenever possible, try to substitute comparable but safer alternatives for human body samples. There are many materials available for purchase that mimic the properties of blood, saliva, and urine. DNA samples for extraction can be done from fresh foods. It is also feasible to substitute laboratory activities with pedagogically- sound CDs or online virtual activities. In many cases, the educational benefits of using human body samples does not out way the inherent risks and required disposal methods associated with these samples. If the use of human body samples is deemed necessary, the following resources provide recommendations regarding the use of human body samples in the life science classroom or laboratory:

i. Teachers must follow school system policy regarding parent/guardian permission and students' rights to refuse to participate in experiments using body fluids.

ii. OSHA Regulation 29CFR 1910.1030 must be followed.

iii. The National Association of Biology Teachers (NABT) Position Statement on "*The Use of Human Body Fluids and Tissue Products in Biology Teaching*".

iv. The Centers for Disease Control (CDC) requires the application of Universal precautions (UP), Standard precautions (SP), and Transmission-based precautions (TBP) related to infection control related to a wide range of infectious disease hazards associated with human body samples.

1. **Universal precautions (UP)**, originally recommended by the CDC in the 1980s, was introduced as an approach to infection control to protect workers from HIV, HBV, and other bloodborne pathogens in human blood and certain other body fluids. UP is an approach to infection control in which all human blood and certain human body fluids are treated as if they are known to be infectious. Although the BBP standard incorporates UP, the infection control community no longer uses UP on its own.

2. **Standard precautions (SP)**, introduced in 1996 in the CDC/Healthcare Infection Control and Prevention Advisory Committee's "1996 Guideline for Isolation Precautions in Hospitals," added additional infection prevention elements to UP in order to protect healthcare workers not only from pathogens in human blood and certain other body fluids, but also pathogens present in body fluids to which UP does not apply. SP

includes hand hygiene; the use of certain types of PPE based on anticipated exposure; safe injection practices; and safe management of contaminated equipment and other items in the patient environment. SP is applied to all samples even when they are not known or suspected to be infectious.

3. **Transmission-based precautions (TBP)** for contact-, droplet-, and airborne-transmissible diseases augment SP with additional controls to interrupt the route(s) of transmission that may not be completely interrupted using SP alone. The different types of TBP are applied based on what is known or suspected about the possible infection risks.

2. Nonhuman

Teachers and school systems need to make informed decisions about the integration of animals in the science curriculum. School systems must ensure that animals are properly cared for and treated humanely, responsibly, and ethically. Decisions to incorporate organisms in the classroom should balance the ethical and responsible care of animals with their educational value.

In all cases, teachers should consult their school system policy as well as organizations and agencies such as the local Humane Society and the State Department of Natural Resources before bringing animals into the classroom. The National Science Teaching Association's (NSTA) Position Statement on Responsible Use of Live Animals and Dissection in the Science Classroom and the National Association of Biology Teachers' (NABT) Principles and Guidelines for the Use of Animals in Precollege Education provide significant guidance.

a. Invertebrates - Invertebrate animals are often used for observation and learning activities. For example, *Drosophila sp.* (the fruit fly), is used in genetics. Anesthetize the organisms carefully by one of the following methods.

i. If experiments are done with fruit flies, take care in quieting them and/or killing them. Using ether in killing jars is not recommended. If ether is used, it should be discarded within a month of opening. One commercial substance used as a substitute for ether contains triethylamine $(C_2H_5)_3N$, which is flammable, toxic by ingestion, and a severe irritant. Use with care. Other methods are:

1. placing the fruit flies in a Petri dish, gently covering them with cotton, and then inverting the dish for examination under the dissecting microscope; and

2. refrigerating culture jars and placing "chilled" flies on a Petri dish over ice.

ii. Anesthetizing kits also may be used. For example, FlyNap® kits containing harmless components may be purchased from biological supply companies.

Any anesthetic should be used in a properly ventilated room according to the supplier. Teachers should obtain manuals available from biological suppliers. These manuals are inexpensive and serve as a complete guide to maintaining and studying the organisms in the classroom.

b. Vertebrates (Nonhuman)

   i. Do not take vertebrates from the natural environment. Most municipalities prohibit the removal of vertebrates from the natural environment. Doing so upsets nature's balance and may introduce unwanted microorganisms or diseased animals into the classroom.

   ii. Obtain animals from a certified disease-free source.

   iii. When studying developing chicken embryos, do not use any embryos that are more than 18 days old.

   iv. Do not work with virus-infected eggs.

   v. Dispose of dead embryos, which may carry pathogenic bacteria. See Chapter 9.C, Microbiology.

   vi. Do not give away or sell any animals, including baby chicks.

   vii. Do not release animals that are not indigenous to the area into the environment. The State Department of Natural Resources must approve release of indigenous animals.

   viii. Md. Code, Criminal Law, § 10-614 prohibits – except for commercial breeding or raising – any person from selling or giving away baby chickens, ducklings, or other fowl under three weeks of age. The law also prohibits staining or in any way coloring such an animal. Any person who violates this law is subject to a $25 fine.

c. Other Guidelines for Working with Animals. These additional guidelines for working with animals protect students and the animals. Most of these guidelines relate to animals in the classroom.

   i. Take care to avoid contact between humans and animals when either of them may be a disease carrier.

   ii. Keep laboratory animals isolated from wild animals.

   iii. Only the student assigned responsibility for animal care should have direct contact with the animals.

   iv. Maintain a good environment for the animals, with ample food and water available to them at all times, including weekends and holidays. Keep cages clean of waste.

v. Protect animals during times of pesticide use.

vi. Sterilize cages and equipment before and after use. Use household bleach, 2% phenol, or Lysol®. Rinse the cage well with water.

vii. Parent/guardian permission must be obtained before allowing a student to take an animal home.

viii. The following animals should not be kept in school:

- venomous reptiles and fish
- black widow and brown recluse spiders
- scorpions
- bees, wasps, hornets, and other stinging insects
- animals at high risk of carrying rabies
- wild animals– particularly mammals

ix. The following animals may be kept at school with the noted cautions:

- turtles and snakes (possible Salmonella infection)
- fur-bearing animals (possible cause of allergies)
- tarantulas (possible bites)
- parakeets and parrots (possible psittacosis infection)

x. Keep aquariums and terrariums clean so that organic materials do not act as a reservoir for microorganisms. Remove mineral accumulations with a vinegar solution and rinse.

d. Dissection. All dissections should be conducted with consideration and appreciation of the organism, be appropriate for the maturity level of the students, and based on specific learning objectives and standards. Teachers should provide suitable and equivalent alternative educational activities for students and parents/guardians who request non-dissection options.

i. Living specimens should be maintained in the laboratory until used.

ii. Live animals being used in dissections should be prepared using an appropriate method by the teacher or by student aides under the direct supervision of the teacher.

iii. Specimens such as frogs can be held for several weeks in the refrigerator.

iv. Preserved specimens and tissues purchased through reputable biological supply companies are acceptable subjects.

v. Animals killed on highways and other non-preserved specimens cannot be used due to exposure to disease and bodily gases and fluids.

vi. Certain specimens, such as fish and squid, and some tissues, such as chicken wings, may be purchased from the local grocery store and should meet USDA standards for human consumption.

vii. Teachers should assess their needs carefully and order only enough material for a year. Specimens and tissues should not be stored from year to year since deterioration may occur.

viii. Before use, specimens and tissues should be kept in their original containers and placed in an area not available to students. Decayed preserved specimens and tissues should be discarded properly. See Chapter 9.C, Microbiology.

ix. Preserved specimens and tissues should be thoroughly rinsed in running water before use.

x. Freeze-dried specimens that have been rehydrated in a dilute 10% alcohol-water solution for 24 hours should be thoroughly rinsed before use.

xi. Specimens are normally preserved in an alcohol-based preservative from the biological supply company. Formalin or formaldehyde should not be used. Acceptable preservatives used by reputable supply companies include Caro-Safe® and Bio-Perm®. Specimens retained for further work on succeeding days should be labeled and refrigerated if possible.

xii. Animal skins can be protected from insect damage by storing them in borax or mothballs.

xiii. While performing dissections, students should wear chemical splash safety goggles, gloves, and aprons.

xiv. Students should wash their hands after any dissection activity.

xv. All equipment used in dissections should be thoroughly cleaned after each laboratory session.

xvi. Students should be given adequate time to clean tools, pans, and dissecting stations before the end of the laboratory session.

xvii. If the dissection is to be continued at a later time, specimens should be placed in plastic bags to prevent desiccation and deterioration. Bags should be clear or clearly labeled.

xviii. Specimens and tissues should be bagged and then discarded in an appropriate manner. See Chapter 9.C, Microbiology.

xix. Chemical preservatives should be discarded according to the disposal instructions in the SDS for the substance. At the conclusion of the laboratory period, everyone must thoroughly wash hands and arms with soap and water, taking care to clean under the fingernails. See Chapter 7.D, Chemical Waste Strategies.

e. Research Procedures

i. Use invertebrates for research when appropriate because of their variety and the considerable number of specimens.

ii. Vertebrates are appropriate in cases where their similarities to humans are important to research. Research should be carried out with qualified adult supervision and the advice of a veterinarian.

iii. Plants should be used wherever possible for experiments on organisms. See Chapter 9.E, Botany and Mycology (Fungi).

E. BOTANY AND MYCOLOGY (FUNGI)

1. Facilities and Equipment

a. Facilities necessary include proper lighting, adequate heat, adequate water, and adequate nutrients.

b. Containers should be cleaned before and after use.

c. Commercial potting mixtures are recommended over garden soil because they are relatively sterile. See Chapter 9.G, Greenhouse Maintenance and Operation.

2. Cautions

a. Allergies. Many people are allergic to pollen, mold spores, or other plant exudates. When using flowers, mushrooms, fungi, etc., in the laboratory, adequate ventilation is essential. Pollen and mold spores should be displayed in closed glass Petri dishes.

b. Seeds. Students should never eat any seeds used in the laboratory. When working with pesticide-treated seeds, the seeds should first be washed. Students should wash with soap and water after handling such seeds.

c. Thorns/Needles. Many plants have thorns or needles. These may be very annoying or even dangerous if contact is made with the skin or eyes. Students should be made aware of the dangers of handling such plants.

d. Toxic Plants. Certain plants and plant parts (as well as fungi) contain harmful substances. Some are poisonous upon skin contact (e.g., poison oak or poison ivy). Gloves help to avoid skin contact. Other plants are poisonous when ingested (e.g., foxglove). No plant should be ingested in the life science laboratory. Students should be made aware of poisonous plants and be able to identify common poisonous plants.

Local health departments or the Maryland Poison Center (MPC) are valuable resources for such information. Phone number for the MPC: 1-800-222-1222.

e. Disposal. Exotic plants should never be released into the environment where they may compete with local plants. Such a release can result in an imbalance to the natural flora (and eventually fauna). For example, the kudzu plant and purple loosestrife have become pests of major proportions.

   Native plants normally do not present a problem for the local environment. Such plants should be discarded in a manner consistent with school policy and local ordinances.

3. Chromatography

a. Chemical splash safety goggles and aprons should be worn. See Chapter 4.A, Eye Protection.

b. Only water baths or hot plates with water baths (and not open-flame fires) should be used for chlorophyll extraction. Extraction may also be accomplished by leaving the plant material in the solvents overnight at room temperature.

c. Only Pyrex or comparable glass tubes should be used.

d. Dissolving and developing solvents give off toxic vapors. They must be stored in closed containers and the room properly ventilated.

e. Solvents are highly flammable and must not be used near an open flame. Avoid skin contact when spraying the developing solvents. Use a fume hood when appropriate. See Chapter 9.D, Zoology: Animal Considerations.

F. BIOTECHNOLOGY AND RECOMBINANT DNA RESEARCH

Work with deoxyribonucleic acid (DNA) is at the core of many of the hands-on activities in molecular biology and biotechnology that have been introduced into the high school life science laboratory. The study of the chemical and physical properties of DNA often involves the spooling, isolation, enzymatic digestion, gel electrophoresis, and manipulation of bacterial cells to introduce new genetic information. Many such laboratory activities can be purchased as complete kits that provide documentation and guidelines helpful to both students and teachers. These kits are especially recommended for teachers who are not familiar with standard procedures in research laboratories. Safety, as always, is a crucial part of any molecular biology experience. Research requiring containment is prohibited.

All research involving recombinant DNA technology must be carried out in accordance with the National Institutes of Health (NIH) guidelines for conducting research using recombinant molecules and organisms. These guidelines are contained in the revised NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules. Essential guidelines for handling any microorganism or DNA molecule in the laboratory are also contained in the “Principles of Biosafety” section of the manual, Biosafety in Microbiological and Biomedical Laboratories. The guidelines include procedures for handling chemicals and microorganisms, maintaining a safe workplace, and disposal (including decontamination) of used materials (including cells).

Escherichia coli (E. coli) is the standard experimental bacterium. *E. coli* is a normal resident of the animal (including human) digestive tract. Many strains of *E. coli* are known. A few strains can cause diseases in humans. Strains of *E. coli* recommended for laboratory use are engineered so they cannot normally survive outside the prescribed conditions of the laboratory. Therefore, these strains pose minor risk of causing disease. However, any opportunistic pathogen can cause problems if appropriate safety precautions are not taken. It is important, therefore, to adhere strictly to accepted microbiological practices with all microorganisms.

1. **Guidelines**

The guidelines below summarize the procedures for working with biotechnology to ensure that the activities will be performed safely.

a. Handle all microorganisms and DNA carefully. Treat them as if they could cause infections.

b. Do not eat, drink, or apply cosmetics in the laboratory. Keep your fingers and writing instruments away from your face and mouth.

c. Hands should be washed with soap and water before and after handling microorganisms and before leaving the laboratory regardless of what materials were used. When handling microorganisms or other living materials, students who have cuts on their hands should wear latex or rubber gloves to protect against infection.

d. Use only mechanical pipetting devices for transferring any material. Do not allow mouth pipetting.

e. Perform procedures carefully to minimize the formation of aerosols. For example, in close proximity to liquid surfaces or the bottom of empty receiving containers, pipet tips tend to form aerosols. Do not force the last drop from a pipet. Keep pipet tips away from the face to avoid inhaling any aerosol that may be formed.

f. Decontaminate work surfaces before and after their use and after a spill. Decontaminating solutions should be readily available and contained in well identified laboratory squeeze bottles.

g. Discard in appropriately marked containers all solid and liquid materials that have come in contact with microorganisms. The containers should be easily accessed by students at each laboratory station.

h. Decontaminate all liquid and solid wastes that have been in contact with experimental microorganisms. Destroy experimental microorganisms before disposal.

i. Glassware (including pipet tips and Eppendorf tubes) that has been in contact with isolated DNA, restriction enzymes, or other non-living materials does not have to be decontaminated. It should, however, be soaked in a disinfectant such as a household bleach solution for an hour and then cleaned thoroughly. Glassware and other equipment that has been in contact with harmless microorganisms may simply be washed thoroughly.

j. Wearing chemical splash safety goggles in the laboratory is recommended. See Chapter 9.C, Microbiology. Guidance may also be available from a university or research laboratory.

2. Staining DNA

a. Methylene blue (or a commercial derivative) is the recommended staining agent for viewing DNA after gel electrophoresis in the high school laboratory.

i. Students should wear nitrile or latex gloves in handling this stain because it is moderately toxic and will stain skin.

ii. In disposing of this stain, follow local regulations. Do not pour methylene blue down the drain without the approval of local authorities.

b. Ethidium bromide, *a staining agent, should only be used by, or under the supervision of, a scientist in a facility where no student exposure will occur*. While it is more sensitive and quicker to use than methylene blue, it is a mutagenic agent.

3. Conducting Gel Electrophoresis

a. Gel boxes purchased from a biological supply company are recommended. These boxes are safe for student use if instructions are followed. If home- built boxes must be used, they should be carefully constructed for safety.

b. Electrophoresis gels are run at high enough electrical voltages (75-140 volts) to cause severe jolts. Students must be warned against sticking fingers or electricity-conducting materials into the electrophoresis buffer solution while the gel box is in operation.

4. Radiation/Radioisotopes

a. Radiation experiments and the use of radioisotopes are highly regulated by the state of Maryland and the federal government. The teacher must be aware of special precautions needed to work with nuclear materials, including issues related to the nature of the radioactive sources, student contact, secure storage, and disposal. There are also license requirements for persons who possess nuclear materials. For different isotopes, federal and state regulations set different limits for possession and use. See Chapter 11.F, Radiation Hazards.

G. GREENHOUSE MAINTENANCE AND OPERATION

For schools that have greenhouses available for life science classes, the following guidelines are intended to aid in their smooth maintenance and operation. These guidelines, which supplement applicable school regulations, apply to any individual working in the greenhouse area, student, or teacher.

1. Guidelines

The following guidelines are designed to ensure that all greenhouse components are functioning at an adequate level for optimum plant growth and at a safe level for student use.

a. Check water lines, heating system, fans, and temperature control. These are usually routine procedures that can be checked by the school maintenance staff.

b. Make sure all automatic equipment is functional and accurate.

c. Clean tools after use and store them appropriately.

d. Instruct students in the proper use of, and conduct in, the greenhouse area. It is recommended that students be required to obtain the teacher's permission to enter the greenhouse.

e. Rules which apply to the greenhouse must be clearly stated and explained to students. It is important that students understand that the rules are for the safety of both the organisms in the greenhouse and the students.

f. Students and teachers should be cautioned to handle fertilizer carefully to avoid inhaling the dust.

g. Wash fruits and vegetables before studying. Eating fruits or vegetables that have been cultivated in the greenhouse is not recommended unless particular care has been maintained in the growth of such plants.

h. Inspect the greenhouse periodically to prevent the cultivation of unlawful plants such as marijuana.

i. Make sure to maintain adequate ventilation. Ventilation is especially important when using pesticides. See the next section Pesticides.

j. Use organic methods of pest control when possible.

k. Maintain all equipment so as not to impede the safe movement into and about the greenhouse. For example, hose lines should be properly mounted and stored to keep the floor clear.

l. Wash hands thoroughly after working in the greenhouse.

2. Pesticides

a. Selecting Pesticides

   i. Check school system policies and regulations about the use of pesticides in schools.

   ii. Use the least toxic pesticides.

   iii. Note signal words found on pesticide labels:

- *Danger* = highly toxic.
- *Warning* = moderately toxic.
- *Caution* = slightly toxic.
- No caution or warning = relatively non-toxic.

iv. The safest insecticides contain pyrethrins.

v. As of January 1, 2022, Maryland banned all pesticides containing chlorpyrifos for all use in the state.

b. Using Pesticides

i. Pesticides are toxic and should be used only according to instructions on container labels.

ii. Pesticides can enter the body through the skin, mouth, or nose. Before using pesticides, cover up exposed skin with water-repellent clothes and boots.

iii. Wear a wide-brimmed hat and a full-face shield.

iv. Use unlined, natural rubber gauntlet gloves.

v. Use exhaust hoods and ventilation systems when spraying.

vi. Do not touch the mouth or face with hands, forearms, or clothing.

vii. Do not expose drink or food containers to pesticides.

viii. Wash hands and face immediately after applying pesticides.

Chapter 10: Earth/Space Science

Earth/space science is an applied science based on many concepts from chemistry and physics. Teachers should become familiar with the precautions in these disciplines found in chapters 3 through 7 and 11. Because Earth/space science relies on remote sensing for observations and data collection, teachers must also be knowledgeable about the hazards inherent in the instruments used for these procedures.

A. MECHANICAL HAZARDS IN EARTH/SPACE SCIENCE

1. **Disposal** – Do not flush sand, silt, clay, rocks, and other earth materials down the drain. These materials are not soluble in water and may clog the drain. Dispose of them in a trash can or other suitable receptacle.

2. **Force Measuring Devices** – Students must be careful when projecting objects (steel balls or marbles). The area should be clear of all obstacles. The devices are used to illustrate laws of motion. See Chapter 4.A, Eye Protection.

3. **Sling Psychrometer** – Care should be exercised in using this device. Be sure the thermometers are securely fastened. This device goes through more wear and tear than other devices due to it having to be spun by hand.

4. **Rocketry** – Take exceptional care when launching a rocket. See Chapter 11.H, Rocketry.

5. **Rocks and Minerals** – When using acids to test minerals, wear protective safety goggles and flush the sample with water after testing. Wear goggles and aprons when breaking up rock and mineral samples. When breaking up rocks and minerals, place the specimens in a heavy canvas bag, use the proper geologic hammer, and wear goggles. When conducting a scratch test with a fingernail, be sure to do this carefully. Thoroughly wash hands after doing the scratch test. Even though taste is a test for identifying certain minerals and rocks (e.g., Halite), do not taste any mineral or rock samples.

6. **Stream Tables** – Be sure that adequate receptacles are available to catch water flow and that all hoses and tables are free of leaks. Use only electrical equipment designed for stream tables to reduce the risk of electrical shock. Goggles should be worn when placing materials in the stream table. Certain materials, like clay or diatomaceous earth, may irritate the eyes. Follow proper disposal procedures for the materials used in the stream tables.

7. **Wind Generating Devices** (Hair Blower, Electric Fan, etc.) – Take particular care in using wind generating devices. As these devices are often used with water, they present a risk of electric shock. No one should disconnect, connect, or operate these devices with wet hands or while standing on a wet floor. Devices having metal housings should be grounded.

B. ELECTRICAL HAZARDS IN EARTH/SPACE SCIENCE

Certain devices used in earth science present electrical hazards. These include batteries, power and extension cords, and various electrical equipment. See Chapter 11.B, Electrical Hazards.

C. LIGHT HAZARDS

1. **Magnesium Ribbon** - Students should not look directly at the flame when a magnesium ribbon is being burned. Extreme brightness can damage the eyes. Burn magnesium ribbon in a well-ventilated area (e.g., fume hood).

2. **Sun** - Radiation from the sun poses an immediate danger to the eye. Do not view the sun directly for any reason. The sun's radiation will be concentrated and burn the retina. This can cause partial or total blindness. Polaroid lenses, welder's goggles, sunglasses, smoked glass, fully exposed photographic film, tinted glasses, and pinholes are not safe for viewing the sun or an eclipse of the sun. Only by indirect methods can a solar eclipse be observed without risking damage to the eye. You may project an image of the sun onto a piece of paper after the image passes through a pinhole or telescope. Photographing an eclipse of the sun requires numerous precautions. Do not observe the sun through an unprotected camera viewfinder. Those interested in such photography are referred to the American Astronomical Society website for more information.

3. **Telescopes and Binoculars** - Eyepieces of shared telescopes and binoculars should be cleaned periodically to reduce the risk of the transmission of eye infections. Never observe the sun directly through a telescope or binoculars.

4. **Ultraviolet Lamps** - Special glasses (such as those coated with an ultraviolet absorbing film) should be used when examining mineral samples with an ultraviolet lamp. Only special goggles clearly designated for the purpose of absorbing ultraviolet light should be used. See Chapter 11.F, Radiation Hazards.

D. FIELD STUDIES

Earth/space science students are frequently involved in outdoor activities such as collecting, mapping, making weather observations, hydrologic studies, and using optical equipment. See Chapter 8, Outdoor and Field Studies Safety.

Chapter 11: Physical Science

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012) attempts to remove the historical division between the two subjects of physics and chemistry by grouping them together as physical science to ensure a more coherent approach to the core ideas across all grades. The designation of physical science courses at the high school level as either physics or chemistry is not precluded by grouping of these disciplines together.

The physical sciences—physics and chemistry—underlie all natural and human created phenomena. An overarching goal for learning in the physical sciences, therefore, is to help students safely see that there are mechanisms of cause and effect in all systems and processes that can be understood through a common set of physical and chemical principles. This study includes a multitude of potential hazards through the chemicals and apparatus that teachers and students interact with. Effective use and control of such hazards involves both the recognition of each hazard and knowledge of the various apparatus. While it is not desirable to eliminate creativity in the interest of safety, teachers should temper their creativity with a constant alertness to potential dangers. Common sense can go a long way toward providing a safe environment. This chapter provides both general and specific rules for those activities frequently performed in the physical science classroom.

A. MECHANICAL HAZARDS

1. **Mechanical Equipment** - Before using any mechanical equipment, check to make sure it is safe to use. Broken or damaged equipment should not be used with students.

2. **Exposed Belts** - Exposed belts and pulleys must be covered with a shield. This prevents the hazard of broken belts, and of fingers or clothing being caught between belts and pulleys. (OSHA Regulations: 29 CFR 1910.219)

3. **Falling Masses** - Heavy masses may be used in experiments involving Atwood's machine, free fall, Newton's laws, and momentum. Warning should be given to students to prevent hands and feet from being caught between a moving heavy mass and floor or table surfaces. Students may not anticipate how difficult it is move or support a lead brick or kilogram mass.

4. **High-speed Rotation** - Rotators are sometimes used to demonstrate centripetal force, circular motion, and sound phenomena. Any device attached to a rotator should be fastened securely and checked for tightness frequently. Observers should avoid contact with moving accessories such as toothed wheels, siren discs, etc. Loose clothing and long hair should be kept away from moving parts, and observers should not be in the plane of rotation. The use of safety goggles should be considered in all student laboratories investigating centripetal force. Extremely high-speed rotation should be avoided when possible. High speeds may cause some objects to fly apart unexpectedly.

   A strobe light is sometimes used to illuminate a rotating object, making the object appear to be at rest. If the object is a fan blade, a toothed wheel, or anything else with sharp edges, there is danger of injury from touching or inserting an object into the apparently stationary object.

Students should be alerted to this danger. Additionally, strobe light may affect students who are photosensitive or have seizure disorders. Consult your students' medical plans as needed.

5. **Magnets** - Large permanent magnets and electromagnets may attract opposite poles or steel objects with unanticipated force. Students should be warned of the potential risk of pinching their hands between an object and the magnet. In addition, exposed terminals on electromagnets should be insulated to prevent electric shock hazards. Electromagnets can also generate heat, so use caution when handling them.

6. **Power Tools** - It may be necessary for students constructing apparatus for physics experiments to use various power tools contained in a wood or metal shop. In these situations, the instructor in charge of these machines should be consulted for proper safety precautions necessary for each tool or machine. Also see Chapter 12.B, Hand and Power Tools.

7. **Projectiles** - In demonstrating the flight of any projectile, students should be kept clear of the path and impact area. The teacher should always pretest the projectile to determine the path it will follow and its range as well as the amount of variability to be expected. Sharp-pointed objects should not be used as projectiles. Use of safety goggles should be strongly considered. A simple mechanical launcher (e.g., compressed spring, compressed air, stretched elastic) should be used. It should only be “loaded” at the specific time a flight is to be observed. The "loading" process should be supervised by the teacher. See Chapter 11.I, Projectile Activities.

8. **Springs** - Stretched or compressed springs contain mechanical potential energy. A stretched spring, unexpectedly released, can pinch fingers. A compressed spring, when suddenly released, can send an object at high velocity toward an observer. Care should be taken to avoid unexpected release of the spring's energy when working with dynamics carts, spring-type simple harmonic oscillators, and springs used in wave demonstrations. Use of safety goggles is strongly recommended.

B. ELECTRICAL HAZARDS

1. Physiological Effects

a. Body Resistance. Students must be warned of the high death potential present even when the voltage is low. The severity of an electrical shock depends primarily on the amount of current to which a person is exposed. Since the current is related to the resistance and voltage, these two factors, as well as the part of the body involved and the duration of the contact, determine the extent of injuries to the victim. If the skin is wet or the surface broken, the resistance drops off rapidly, permitting the current to flow readily through the bloodstream and body tissues.

See chart below for relative hazards of electric shock.

Mode of Electric Contact	R (S)	I (mA)
one dry finger on each electrode	100,000	1.1

Mode of Electric Contact	R (S)	I (mA)
one wet finger on each electrode	40,000	2.8
one salt/wet finger on each electrode	16,000	6.8
tight grip on each electrode	1,200	92.0

b. Current-Resistance Relationship. Ohm's law indicates that the amount of current in amperes flowing in a circuit varies directly with the electrical potential applied in volts (V) and varies inversely with the resistance (R) in ohms: I = V/R

Thus, one can calculate the expected current in a given situation.

Example: Let R for a damp hand = 1,000 ohms. If an electrical potential of 110 volts is applied across the hand, the current would be: I = 110 Volts = 0.11 A or 110 mA 1,000 ohms

The table below illustrates how the various current values affect human beings. The readings are approximate and vary among individuals. In view of the information below, it would be sound practice never to receive an electrical shock under any circumstances if it can be avoided.

Current (mA) AC (60 Hz)	Current (mA) DC	Effect
1-3	5	mild perception
6-9	70	paralysis, inability to let go
25	80	danger to life from heart and respiratory failure
100	100	fibrillation, death

c. Burns. Many electrical devices become quite hot while in use. In addition, "shorted" dry cells and batteries can produce extremely hot temperatures. Students should never grasp a recently operated device or wiring without first checking for excess heat.

2. Electrical Apparatus

a. Batteries. A battery is an unregulated source of current capable of producing large currents when resistance is low. When short-circuited, connecting wires can become extremely hot, raising the risk of burns. Short- circuited mercury batteries may even explode. Chemical leakage from batteries is a potential hazard, especially in the case of wet cells that contain caustic chemicals such as sulfuric acid.

Certain types of batteries are rechargeable while others are not. Carbon- zinc and nickel-cadmium type batteries can be recharged. Do not, however, attempt to recharge a completely dead carbon-zinc battery, a leaking or corroded battery, or any battery that carries a warning against recharging. Such batteries can cause damage to the charger and may explode, causing personal injury. Lead-acid batteries can be recharged but produce explosive hydrogen gas during the process. They should only be recharged in a well-ventilated area with an appropriate charger.

b. Capacitors. Capacitors are used to store electric charge. They may remain charged for lengthy periods after power is turned off, and they therefore pose a serious shock/burn hazard. Before working on any circuit containing a capacitor, make sure that it is discharged by shorting its terminals with an insulated wire or screwdriver. Oil-filled capacitors may sometimes recharge themselves and should be kept shorted when not in use. Oil from older capacitors may be contaminated with dangerous PCBs.

   When installing electrolytic-type capacitors in a circuit, proper polarity rules must be followed (negative to negative and positive to positive). Improper connection can result in an explosion. Be on the lookout for capacitors in any apparatus with high voltage components such as oscilloscopes, TV sets, lasers, computers, and power supplies. Electrostatic generators and Leyden Jars are also capacitors and can be a source of unexpected shock.

c. Circuit Loads. Most school laboratory electrical circuits have a maximum power rating of 1,500 watts (if fuses are 15 amp) or 2,000 watts (if fuses are 20 amp). The total power load on a circuit should not exceed these values. The total load is the sum of the power ratings of all apparatus plugged into that circuit. The individual power rating is usually found printed on a plate somewhere on the apparatus.

d. Electrostatic Generators. Electrostatic generators used in demonstrations of static electricity produce high voltages (about 105 volts) with incredibly low currents. The danger of these generators depends on their size and capacity to produce enough current to be dangerous. In many cases the shock from such devices is very quick and not harmful. The startling effect, however, can be detrimental to persons with heart conditions.

   In general, experiments that use human subjects to demonstrate the effect of electrical shock should not be attempted due to the large variation in physical and physiological factors. Leyden jars -- which can be charged with electrostatic generators -- are especially dangerous because of their capacity to store a charge for lengthy periods of time. An accidental discharge through a person can be avoided by properly shorting the devices after use.

e. Extension Cords. Use extension cords only when there is no convenient way to connect equipment directly to a receptacle. If an extension cord must be used, it should be checked for damage, proper grounding, and electrical capacity. An extension cord should be marked with its capacity in amperes and watts and the total load should not exceed these values. If the cord is unmarked, assume that it is 9 amperes or 1,125 watts. If an extension cord becomes very warm to the touch, it should be disconnected and checked for proper size. In general, science laboratories should be equipped with sufficient receptacles to minimize extension cord use.

f. Fuses/Circuit Breakers. Replace blown equipment fuses with fuses of the same amperage. Replace fuses with the equipment unplugged. Failure to use the correct fuse can cause damage to equipment and overheating. Frequent blowing of circuit fuses or tripping of circuit breakers usually indicates that the circuit is overloaded or a short exists. Circuit breakers and fuses that are tripped or blown should be turned on or replaced only after the cause of the short or overload is removed from the circuit. The school's Building Operations Staff can assist with replacing fuses and/or resetting circuit breakers.

g. Grounding. Use grounded 3-prong plugs when available. If the outlet is 2-prong, use an adapter and secure the ground wire to the cover-plate screw on the outlet. Grounding is particularly important for the light sources used with ripple tanks since these lights are suspended above the water in the tanks. Any apparatus with a metallic case or exposed metal parts should be checked to make sure that the case is grounded. Such ungrounded appliances should be retrofitted with a ground wire and three- pronged plug. The use of ground-fault interrupters should be considered.

h. Power Cords. Any power cord should be inspected periodically and replaced immediately if frayed or damaged. Apparatus should be located to keep power cords away from student traffic paths. When removing the cord from an outlet, the plug should be pulled, not the power cord. Wet hands and floors present a hazard when connecting or disconnecting electrical apparatus.

i. Hot plates. See Chapter 6.D, Heat Sources.

C. VACUUM AND PRESSURE HAZARDS

1. Vacuums

a. Suitable Containers. Many popular physics demonstrations utilize a small vacuum pump to evacuate a chamber such as a bell jar, a coin-feather tube, or a collapsing metal can. Under no circumstances should a standard thin-walled, flat-bottom jar be evacuated because of the likelihood of implosion. If students are to be allowed to pump out a well-designed chamber, make sure it is mounted so it cannot tip over and implode when under vacuum. Any large evacuated chamber should be equipped with a screen shield to help provide protection following an implosion. If a screen shield is not available, wear safety goggles.

Such implosions can result from long-term stresses in glass or may result from thermal effects if heating occurs without opportunity to expand. On small chambers where a screen is inconvenient or undesirable, the walls should be wrapped with tape to reduce the flying glass following an implosion. When bell jars are used in demonstrations, remind students that they are specifically designed to withstand atmospheric pressure, and that one should never pump on a conventional container. Full face shields should be worn whenever working with a system which could conceivably implode or explode.

b. Tubes and Implosions. Vacuum tubes, especially large ones, present a safety hazard if the tube breaks. Flying glass and electrodes can travel great distances when a tube implodes. This is a particular danger when tubes such as a cathode ray tube, a TV picture tube, or a Crookes tube are used in a demonstration or experiment that removes them from the protective housing. Under these conditions, all observers should wear safety goggles or shields.

   When an inoperable tube is to be discarded, it should be covered with a heavy canvas cloth and broken by striking the rear of the tube with a hammer. The broken tube should then be carefully disposed of.

c. Vacuum Pumps. Vacuum pumps equipped with belts and pulleys must have the belt and pulley system shielded to prevent clothing and hands from getting caught. This shield should also prevent injury from broken belts striking nearby observers. Students should be warned to be careful of the hot motor and other parts after operation. (OSHA Regulations: 29 CFR 1910.219).

2. Pressures

a. Compressed Air. Students in laboratories equipped with compressed air at lab stations or lecture tables should be warned of the danger of blowing dust or other debris into the eyes accidentally with compressed air. Use of safety goggles is strongly recommended. High pressure air directed at glassware for drying purposes can provide enough force to knock containers from the hands. The flow of air should be adjusted first to prevent this hazard.

b. Gas Bottles. One of the most common items to be found in any science laboratory is a container of compressed gas. The pressures in gas containers may vary from atmospheric pressure to 10,000 psi, with most tanks designed as shipping containers (with a minimum weight and wall thickness). A container of gas should not be kept around if the gas and its characteristics are unknown. When a gas cylinder tips over and is damaged, it can become a high powered, massive rocket capable of going through many walls and people. See Chapter 6.K, Compressed Gas.

   Almost all cylinders have internal pressures greatly exceeding what is needed for an experimental apparatus. Small laboratory lecture bottles may be controlled with a needle valve as long as they are not discharging into a system allowing pressure to build up to bottle pressure. Large cylinders should be controlled by a single or double stage regulator of a suitable pressure range. When a regulator is being used, the main cylinder valve should still be closed each time an experiment is shut down since regulators are not made to be reliable shut-off valves.

If compressed gas is used as a propellant, students should remain clear of the gas exhaust and propelled objects. See Chapter 11.A, Mechanical Hazards and Chapter 11.I, Projectile Activities.

c. Generating Gases. A pressure relief safety valve of some type should be an integral part of any system constructed to generate gas or steam.

D. HEAT AND CRYOGENIC HAZARDS

1. Heat

a. Heating Procedures. Often it is necessary to heat liquids and solids in physical science experiments and demonstrations. It is safer to use water baths and hot plates than to heat directly with open flames such as with Bunsen burners.

i. Inspect all glassware carefully before using it. Glassware must be free of chips and cracks.

ii. Any glass apparatus that is to be heated should be made of Pyrex® brand or Kimax® brand.

iii. Never heat a closed container if there is no means of pressure relief.

iv. Many substances, especially glass, remain hot for a long time after they are removed from the heat source. Always check objects by bringing the back of the hand near them before attempting to pick them up without tongs, hot pads, or gloves.

v. Never set hot glassware on cold surfaces or in any other way change its temperature suddenly, because uneven contraction may cause breakage.

See Chapter 6, Safe Handling of Equipment, for additional information on heating, gas burners, and glassware.

b. Steam. Live steam is generated in experiments to determine coefficients of thermal expansion and the heat of vaporization of water. Potential hazards can be avoided by following a few simple guidelines.

i. Produce steam only in a container with a direct open line to the atmosphere.

ii. Instruct students that steam has an extremely high heat capacity and is invisible (the visible “vapor” is already condensed droplets). Caution them not to aim steam outlets at their own skin or at other students.

iii. Production of steam under pressures higher than atmospheric pressure should be limited to teacher demonstrations. The teacher should take necessary precautions associated with the higher temperatures of this steam and the explosion hazards.

c. Thermometers. Thermometers present several possible hazards in the laboratory related to breakage. Following the guidelines below will minimize the hazards.

   ii. Inspect thermometers before using them. If the thermometer stem is chipped, cracked, or broken, do not use it and dispose of it properly.

   iii. Use only alcohol thermometers. Md. Code, Environment §6-906 prohibits the use of mercury filled thermometers in primary or secondary classrooms.

   iv. Consider the range of temperatures to be measured when choosing a thermometer. If heated beyond its capacity, a thermometer may break.

   v. Mount a thermometer in a safety rubber stopper whenever possible. When using other types of stoppers, use a lubricant on the glass or a split stopper. If necessary to free the thermometer from the stopper, split the stopper with a single-edge razor blade. Teachers should ensure that students use the thermometer in such a way that the equipment does not become unstable. See Chapter 6.C, Thermometers, for guidelines on using thermometers.

d. Burns. A common cause of student injury is a burn from recently heated glassware. To avoid such burns, check the glassware by bringing the back of the hand close before attempting to pick it up. In case of an accidental burn, administer first aid and visit the appropriate health care person in the school.

e. Asbestos**.** Many older hot plates, hair dryers and other heating elements contain wires or parts insulated with asbestos. Since the dangers of asbestos are well documented, all efforts should be made to replace this equipment with non-asbestos-insulated apparatus.

2. Cryogenics

a. Dry ice (solid carbon dioxide) is used in some low-friction pucks, as a source of carbon dioxide gas, and as a cooling agent. A mixture of dry ice and alcohol or liquid nitrogen might also be used in low-temperature baths. The temperatures of these materials are low enough to cause tissue damage from a cryogenic “burn.” This is not likely to occur if contact is brief, because the vapor layer formed between the cryogen and the tissue is not a good conductor of heat. Follow the guidelines below to avoid a dry ice “burn.”

b. Flush the skin that came into contact with the dry ice with water. Water should always be readily available during cryogenic experiments.

c. In preparing a dry ice/alcohol mixture, pour the alcohol over the dry ice rather than dropping the dry ice into the alcohol to avoid spattering. When storing alcohol that has been used in a dry ice/alcohol mixture, the alcohol should be returned to room temperature to allow the escape of excess dissolved gas before placing in a closed container.

d. When dry ice is used in a confined space, provide sufficient ventilation to eliminate the risk of asphyxiation. This risk is caused when the denser carbon dioxide gas released produces an oxygen-deficient layer.

e. Used to produce a special effect (such as fog in a drama production), dry ice may produce substantial amounts of carbon dioxide. Students and other teachers should be warned of this risk and informed about avoiding it.

f. Cryogens should be kept in double-walled containers such as Thermos bottles or Dewars. Any fluid which gets between the walls at low temperatures may become trapped and vaporize at higher temperatures, building up pressure and exploding the container. The outer wall should be heavily wrapped to avoid this hazard.

E. CHEMICAL HAZARDS

1. **Chemical Management, Handling and Disposal** - See Chapter 7, Chemical Management, Handling and Disposal.

2. **Carbon Dioxide** - The use of dry ice in cryogenic experiments must be accompanied by precautions against production of an oxygen-deficient atmosphere. Carbon dioxide, which is denser than air, easily collects in a non-ventilated area. See Chapter 11.D, Heat and Cryogenic Hazards.

3. **Carbon Monoxide** - Do not allow carbon monoxide from incomplete combustion to collect in a closed area. Always conduct demonstrations using small internal combustion engines under a vented hood or outdoors.

4. **Explosives** - Do not attempt to make explosive compounds such as those that might be used in model rocketry. Only factory-made, pre-loaded rocket engines should be used for this purpose.

5. **Flammables** - Do not use flammable substances near an open flame unless the purpose is to demonstrate flammability. Many flammables produce toxic fumes and should be burned only under a vented hood. Large containers of flammable liquids should be opened, and liquids transferred, in a room free from open flames or electrical arcs and, preferably, under a fume hood. See Chapter 7.B, Managing Chemicals, and Chapter 7.C, Handling Chemicals.

6. **Mercury** - Mercury and its compounds, both organic and inorganic, are health hazards. Metallic mercury has a measurable vapor pressure, and the production of vapor is accentuated by heating the mercury or subdividing as occurs in a spill. Laboratory sources of mercury include, among others, thermometers, manometers (barometers), and batteries. Not only is the vapor harmful, but the metal itself is absorbable through the intact skin. Md. Code, Environment §6-

906 prohibits the use or purchase of elemental or chemical mercury in primary or secondary classrooms. Any mercury or devices containing mercury found in a school should be removed by a certified hazardous waste disposal company. Each school system should have a contract with a company able to remove and dispose of the mercury. See Chapter 7.C, Handling Chemicals in case mercury is found after a device containing it breaks.

7. **Other Heavy Metals/Solder** - Highly toxic cadmium oxide may be produced when silver solder containing cadmium is overheated. Some solders contain flux, which may produce noxious fumes. Use fume hoods when working with these materials.

F. RADIATION HAZARDS

1. **Infrared Radiation -** Caution students that, beyond a limited exposure, infrared waves (heat waves) entering the eye can cause burns to the cells of the retina. Infrared lamps and the sun are concentrated sources of these waves.

   a. Follow manufacturer's instructions when using any infrared lamp.

   b. The sun should never be viewed directly, especially at times when its visible light is partially obscured. (The visible light triggers the body's natural defenses of avoidance and pupil constriction.) Lenses and sunglasses do not offer protection from this radiation. Safe viewing of the sun can be done by projecting an image of it through an exceedingly small hole onto a white piece of paper about one-half meter behind the hole. See Chapter 10.C, Light Hazards.

2. **Microwaves -** A microwave apparatus is often used to demonstrate various wave behaviors of electromagnetic radiation. Microwave devices designed for high school use have sufficiently low power to be free of radiation hazards when the manufacturer's instructions are followed. Microwave ovens that are in good working order and used properly do not pose any safety hazard in a classroom. Follow these guidelines:

   a. Check the apparatus for radiation leakage before use if there are any doubts about its safety.

   b. Inspect ovens periodically to ensure they are clean and the door, hinges, vision screen, seals, and locks are secure and working properly.

   c. Do not place metal objects in the heating cavity.

   d. Do not permit students to stand close to an oven during operation.

3. **Radioisotopes -** The use of radioisotopes is highly regulated by the state of Maryland and the federal government. Radioisotopes produce biological injury (cell damage) resulting from their ionizing properties. Gamma rays and beta particles are hazardous both inside and outside the body. Alpha particles cannot penetrate skin and are not hazardous if kept outside the body. The use of license-exempt quantities - especially sealed sources - will create minimum hazard because of the small amount of radiation present. Review the United States Nuclear Regulatory

Commission (NRC) website for further information about sealed sources and license-exempt products and regulations. Safe handling requires these protective measures:

a. *Time*. Minimize contact time with samples.

b. *Distance*. Use tongs, forceps, etc., to avoid direct contact.

c. *Shielding*. Use shielding appropriate for the radiation encountered.

d. *Storage*. Store radioactive materials so that people are not in frequent close proximity to them, and they are not damaged accidentally.

4. **Ultraviolet Radiation** - Ultraviolet light can be absorbed in the outer layers of the eye, producing an inflammation known as conjunctivitis. The effect usually appears several hours after exposure and, unless the exposure is severe, will disappear within several days. Sources of harmful ultraviolet light likely to be encountered in physical science include mercury vapor lamps, electrical arcs (e.g., the carbon arc lamp), incandescent ultraviolet lamps, and the sun.

   a. Mercury vapor lamps and electric arcs should not be observed without elimination of their ultraviolet emissions.

   b. Plastic or glass sheets which transmit poorly in the ultraviolet region offer good protection for the viewer of these sources.

   c. Use black paper with caution because, while it absorbs well in the visible range, it may be highly reflective in the ultraviolet range.

   d. The sun should never be observed directly. See Chapter 11.F, Radiation Hazards.

   e. Incandescent ultraviolet lamps present a minimal danger from their ultraviolet emissions, as the energy of this radiation is extremely low. These bulbs, however, get extremely hot when in use and must be given plenty of time to cool before handling.

5. **Visible Light (including Lasers)** - Intense sources of visible light are usually not hazardous due to the inability of the human eye to remain focused on an intense source. Infrared and ultraviolet radiation sometimes present along with visible light provides a greater hazard. See the Laser Safety section next.

6. **X-ray Radiation** - X-rays may be produced in any situation in which high-speed electrons strike a target. These conditions may exist in evacuated tubes where the accelerating voltages are in the range of 10,000 volts or more. Crookes tubes and other cold cathode discharge tubes are potential sources of X-rays in the classroom. (Spectrum tubes used to observe spectra of elements and compounds are not a source of X-rays if the tubes are in good condition because the enclosed gases prevent electrons from achieving a high enough energy.) To minimize X-ray exposure, teachers and students should observe three rules:

   a. Minimize the voltages used to operate vacuum tubes.

b. Maximize the distance between the tube and the observers.

c. Minimize the time during which the tube is operated. If any tube or apparatus is suspected of emitting X-rays, it should be checked for dangerous amounts of radiation.

G. LASER SAFETY

The laser produces an intense, highly directional beam of light that, if directed, reflected, or focused upon an object, is partially absorbed, raising the temperature of the surface and/or the interior of the object. Potentially, this can cause an alteration or deformation of the material. These properties can cause adverse biological effects in tissue. Photochemical effects are also a danger when the wavelength of the laser radiation is sufficiently short (i.e., in the ultraviolet or blue light region of the spectrum). Low-power lasers may emit levels of light that are not a hazard or are no more hazardous than an electric light bulb.

Some lasers concentrate visible light to an extent that retinal damage can occur in a brief time. Fortunately, these lasers are not often found in secondary school science laboratories. Most lasers used in secondary school laboratories are the continuous wave, low power (0.5 - 3.0 mW), helium-neon lasers. The only optical danger is damage to the retina if a subject looks directly into the beam or non-diffused reflection. The diameter of the beam, the time of exposure, blink response time, and retina spot size all can affect the probability of injury. Since some of these lasers in this range are considered Class 3 lasers (see chart below), certain safety precautions are important to teach and use when working with lasers.

1. Biological Effects

The human body is vulnerable to the outputs of some lasers and can, under certain circumstances, incur damage to the eye and skin. The human eye is always more vulnerable to injury than human skin. In the near- ultraviolet region and in the near-infrared region at certain wavelengths, the lens of the eye may be vulnerable to injury.

Of greatest concern, however, is laser exposure in the retinal hazard region of the optical spectrum, approximately 400 nm (violet light) to 1400 nm (near- infrared). Within this special region, collimated laser rays focus in a very tiny spot on the retina. This hazard only exists if the eye is focused at a distance; reflecting the laser light off diffuse surfaces also prevents the hazard. Higher levels of laser radiation would be necessary to cause injury.

Since this ocular focusing effect does not apply to the skin, the skin is far less vulnerable to injury from these wavelengths. The light entering the eye from a collimated beam in the retinal hazard region is concentrated by a factor of 100,000 times when it strikes the retina.

2. Safety Standards

A system of laser hazard categories has been developed based on millions of hours of laboratory and industry laser use. ANSI Z136.1-2022 classifies each type of laser by its potential for biological harm. These classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B, and Class 4, with Class 1 lasers being exempt from any kind of control due to their lack of hazard and Class 4 lasers requiring strict controls in order to reduce the risk of exposure to the eyes or skin. The safety measures to reduce or eliminate accidents depend upon which class of laser is being used. See the chart below for laser risk classes and their hazards.

Class	Emits (mW)	Hazard	Examples
1, 1M	<0.39	Non-hazardous. Safe for unaided eye exposure. Hazard increases if viewed with optical aids.	laser printer, CD or DVD players
2, 2M	<1.0	Hazardous if looked at continuously or with optical aids. May be viewed directly for less than 0.25 seconds. Eye damage is typically prevented by natural aversion reflexes.	bar code scanner
3R	<5.0	Hazardous when directly viewed or when staring directly at the beam with the unaided eye. The risk of injury increases when viewed with optical aids.	laser pointers
3B	<500	Immediate skin hazard from direct beam and immediate eye hazard when viewed directly. Viewing by diffuse reflection is safe.	laser light shows projectors, industrial laser, research lasers
4	>500	Immediate skin and eye hazard from exposure from either direct or reflected beam. May also present a fire hazard.	laser light shows projectors, industrial laser, research lasers, medical device lasers for eye surgery or skin treatments

3. Laser Guidelines

Lasers can be used safely through the use of suitable facilities, equipment, and well-trained personnel. Class 2 lasers require no special safety measures. However, as in the case of a movie projector, a person should not stare directly into the projection beam. Safety training is desirable for those working with Class 3 systems. Eyewear may be necessary if intrabeam viewing cannot be precluded. Operation within a marked, controlled area is also recommended. Finally, for Class 4 lasers or laser systems, eye protectors are always required; facility interlocks and further safeguards provide additional protection.

Laser pointers have educational purposes, but they also come with a history of misuse and abuse. Teachers must monitor students so that they are not using the laser pointers inappropriately. Md. Code, Criminal Law §3-806 and §3-807 prohibits the use of a laser pointer to illuminate another in a public place in a manner that harasses or endangers the other or knowingly and willfully shine, point, or focus the beam of a laser pointer on an individual operating an aircraft. Additionally, laser pointers not purchased through reputable laboratory supply companies may be misclassified or mislabeled and emit a higher level of output power than expected, therefore requiring additional safety precautions.

The following general guidelines for safe laser use in the classroom are excerpted from Laser Fundamentals and Experiments (1970).

a. Before operation, warn all individuals present of the potential hazard.

b. In conspicuous locations inside and outside the work area and on doors giving access to the area, place hazardous warning signs indicating that a laser is in operation and may be hazardous.

c. Do not at any time look into the primary beam of a laser.

d. Do not aim the laser with the eye. Direct reflection can cause eye damage.

e. Do not look at reflections of the beam. These, too, can cause retinal burns.

f. Do not use sunglasses to protect the eyes. If laser safety goggles are used, be certain they are designed for use with the laser being used.

g. Report any afterimage to a doctor, preferably an ophthalmologist who has had experience with retinal burns. Retinal damage is possible.

h. Do not leave a laser unattended.

i. View holograms only with a diverged laser beam. Be sure the diverging lens is attached to the laser.

j. Remove all watches and rings before changing or altering the experimental setup. Shiny jewelry can cause hazardous reflections.

k. Practice good housekeeping in the lab to ensure that no device, tool, or other reflective material is left in the path of the beam.

l. Before a laser operation, prepare a detailed operating procedure outlining operation.

m. Whenever a laser is operated outside the visible range (such as a CO2 laser), a warning device must be installed to indicate its operation.

n. A key switch to lock the high voltage supply should be installed.

o. Use the laser away from areas where the uninformed and curious might be attracted by its operation.

p. Illuminate the area as brightly as possible to constrict the pupils of the observers.

q. Set up the laser so that the beam path is not at normal eye level (i.e., so it is below 3 feet or above 6½ feet.

r. Use shields to prevent strong reflections and the direct beam from going beyond the area needed for the demonstration or experiments.

s. The target of the beam should be a diffuse material capable of absorbing the beam and reflection.

t. Cover all exposed wiring and glass on the laser with a shield to prevent shock and contain any explosions of the laser materials. Be sure all non- energized parts of the equipment are grounded.

H. ROCKETRY

1. **Local Regulations -** Before beginning a model rocket program, check local school system regulations on the use of model rockets. Be sure also to check regulations about launch sites and fire codes in your area. Local ordinances may be based on NFPA 1122 (2018).

2. **Model Rocketry Safety Code -** Follow the guidelines for safe launching and recovery of model rockets outlined below.

    a. Construction. In making model rockets, use only lightweight materials such as paper, wood, plastic, and rubber; use no metal as structural parts.

    b. Engines. Use only pre-loaded, factory-made model rocket engines in the manner recommended by the manufacturer. Do not alter or attempt to reload the engines.

    c. Flying Conditions. Do not launch a rocket in high winds or near buildings, power lines, tall trees, low flying aircraft, or under any conditions that might endanger people or property, such as the threat of lightning.

    d. Jet Deflector. The launcher must have a jet deflector device to prevent the engine exhaust from hitting the ground directly.

    e. Launch Area. Always launch rockets from a cleared area that is free of any easy-to-burn materials, use non-flammable recovery wadding.

    f. Launch Rod. To prevent accidental eye injury, always place the launcher so the end of the rod is above eye level or cap the end of the rod with the hand when approaching it. Never place head or body over the launching rod. When the launcher is not in use, always store it so that the launch rod is not in an upright position.

g. Launch Safety. Do not let anyone approach a model rocket on a launcher until making sure that either the safety interlock key has been removed or the battery has been disconnected from the launcher.

h. Launch Targets and Angle. Do not launch a rocket so its flight path will carry it against a target on the ground; never use an explosive warhead nor a payload that is intended to be flammable. The launching device must always be pointed within 30 degrees of vertical.

i. Launching System. The system used to launch model rockets must be remotely controlled and electrically operated and must contain a switch that will return to "off" when released. All people should remain at least 10 feet from any rocket that is being launched.

j. Power Lines. Never attempt to recover a rocket from a power line or other dangerous places.

k. Pre-Launch Test. When conducting research activities with unproven designs or methods, try to determine their reliability through pre-launch tests. Conduct launching of unproven designs in complete isolation from persons not participating in the actual launching.

l. Recovery. Always use a rocket system with model rockets that will return them safely to the ground so that they may be flown again.

m. Stability. Check the stability of model rockets before their first flight, except when launching models of proven stability.

n. Weight Limits. Model rockets must weigh no more than 453 grams (16 oz.) at liftoff, and the engine must contain no more than 113 grams (4 oz.) of propellant.

For further information about model rockets and model rocket safety see the Estes Rockets, the National Association of Rocketry (NAR) or the NASA websites.

I. PROJECTILE ACTIVITIES

In some physical science activities, the students may need to create a device to launch a projectile or accurately predict the path of a projectile (ex. catapults, CO_2 cars, etc.). There are a number of risks associated with projectiles because of the velocity and weight of the objects being projected. The following guidelines should be exercised when conducting projectile activities:

1. All participants and observers must wear appropriately impact rated safety glasses or goggles.

2. Sharp pointed objects should never be used as projectiles.

3. Establish a safety zone and keep students clear of the projectile's path or impact area.

4. Teachers should pre-test the projectile activity to determine the path, range, and potential variability.
5. Purchase launch equipment from a reputable vendor and do not attempt to alter the launcher.
6. The launch device should only be loaded when a projectile is ready to be launched.
7. Make sure the trajectory for catapult or other projectiles is marked off and do not allow anyone to stand in its path.

Chapter 12: Engineering, Technology, and Application of Science

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012) highlights that students should learn how science is utilized, in particular through the engineering design process, and they should come to appreciate the distinctions and relationships between engineering, technology, and applications of science (ETS). The Framework introduces two ETS core ideas, Engineering Design and Links Among Engineering, Technology, Science, and Society.

Engineering design includes the process of developing practical solutions to an identified problem. Initial designs of these solutions may be communicated through informal sketches or diagrams, although they typically become more formalized through models. The need to build physical models may be essential to the design process but also potentially includes safety concerns. This has led schools to create or develop Fab Labs, Makerspaces and STEM labs. There are many benefits of these spaces but also challenges and safety concerns. This chapter is not able to highlight all possible situations present in a particular space so additional resources may be needed such as Safer Makerspaces, Fab Labs, and STEM Labs: A Collaborative Guide or Safer Engineering and CTE Instruction: A National STEM Education Imperative by Kenneth Roy Ph.D. and Tyler Love Ph.D.

A. FACILITIES

1. Safety Equipment

It is important to make sure that the spaces or classrooms used for engineering design have similar safety equipment as science laboratories. Such as:

a. access to eyewash stations and showers,

b. fully stocked first-aid kits,

c. emergency power shut-off controls,

d. fire extinguishers and fire blankets,

e. student and teacher personal protective equipment (PPE),

f. safety posters or signs, and

g. appropriate storage cabinets for chemicals and flammables.

See Chapter 3, Safety Concerns and Safety Equipment.

2. Additional Safety Procedures

These safety procedures would be unique to spaces that contain machinery that students might use.

a. Enclose all gears, pulleys, moving belts, chains, and other power transmission devices in permanent guards.

b. Provide and require the use of point of operation guards. These guards are used where the work or action takes place. For example, surrounding a grinding wheel, or over a saw blade.

c. Fasten all stationary equipment, machines, and benches to the floor.

d. Provide for the storage of equipment and machine accessories.

e. Use painted lines on the floor to clearly establish aisles, hazards, and machine operator zones.

f. Use OSHA color-coding on hazardous equipment and machines such as red to identify stop buttons and yellow to designate caution.

g. Place warning signs on machines and equipment unsafe to operate due to malfunction. Ensure that all signs are in any language spoken by the students using the equipment. It is best to lock the control switch and shut off electricity at the power box. A Lockout/Tagout procedure must be used to prevent machines and equipment from being energized during repair and or maintenance.

B. HAND AND POWER TOOLS

Hand and power tools are becoming more common in science laboratories as part of the engineering design process to develop solutions to a problem or STEM challenge. These tools can transform materials into a finished project but can also provide some safety risks for the students. Before allowing students to use hand tools or power tools, teachers are expected to demonstrate the safe and practical application of that tool and the corresponding PPE needed. Do not assume that students know the names and functions of any of the tools they will be using.

1. General Guidelines

a. Never let students use any tool the teacher feels uncomfortable with or does not know how to use!

b. Demonstrate and properly model the safe use of all tools that students will be using.

c. Provide supervision and guidance throughout activities involving hand and power tools.

d. Tools need to be used and stored appropriately in a secure location to which only the teacher has access.

e. Teachers should account for all tools at the conclusion of all activities or class periods.

f. Ensure that all tools are in good working order before being used by students. Do not use tools with loose or damaged handles, mushroomed or splintering ends, missing/broken guards.

g. Tools should be the proper size for the age and size of the students.

h. Only power tools with a 3-pronged grounding type plug should be used.

i. Cutting tools should be kept sharp and in good working order. The sharpness of a tool is essential for safety. Dull blades have the potential to reduce control and cause greater physical harm.

j. The insulation of tool handles is necessary when working with electricity.

k. Discard any hammer if it is dented, chipped, mushroomed, has a loose head, split handle or shows excessive wear.

2. Safety Precautions

a. Remove all jewelry, eliminate loose clothing, and confine long hair before using any tool.

b. Open-toed shoes should not be permitted when working with tools.

c. Students should demonstrate an understanding of safe tool use to the teacher before working independently.

d. All tools should be used in the way they were intended. Misuse can result in damage to the tools and injury (using a screwdriver as a chisel).

e. Avoid using power tools in wet or damp conditions unless approved by the manufacturer.

f. Keep hands clear of all cut lines or areas of impact.

g. Conduct all maintenance or adjustments with power tools unplugged or battery packs removed.

h. Never leave a blade or tool unattended and exposed.

i. Do not leave any tool hanging over the edge of a workbench or table.

j. Wherever possible a jig or vise should be used to hold materials, allowing students to have both hands free.

k. Gloves may protect students' hands from accidental injury and should be a consideration for PPE when using saws, sharp instruments, and other cutting tools.

l. Impact tools, like hammers, may potentially cause discarded debris to fly, and every student within the work area should always wear safety glasses or goggles.

m. Gloves and safety glasses or goggles should be worn by students when working with thermal tools like hot glue guns, soldering irons, and heat guns.

n. Students exposed to 85 dB or higher when operating a power tool should be required to wear professional grade hearing protection devices with appropriate Noise Reduction Ratings such as earplugs, canal caps and or muffs.

o. Students working with tools that generate airborne hazards such as dust, smoke, etc., should utilize appropriate professional respiratory protection. OSHA identified that, the “primary objective shall be to prevent atmospheric contamination through engineering controls - when not feasible, appropriate respirators shall be used.” (29 CFR 1910.134) Respirators must be National Institute for Occupational Safety and Health (NIOSH) certified.

C. FABRICATION TOOLS

Beyond hand and power tools are several types of fabrication tools. These tools use more power and operate at higher speeds, temperatures, etc., and require specialized training and skill to operate. This equipment should only be operated by a student after the student and parent/guardian have signed a safety acknowledgement form, the teacher has provided demonstration and training on the safe use of the machine and the student has passed a safety test (90% or above). Students should not be allowed to use fabrication without direct supervision of a teacher or trained adult.

1. Woodworking Equipment

To produce wood products a number of extremely hazardous machines are needed such as belt/disc sanders, scroll saws, band saws, planers, table saws, routers, etc. Wood products produced could include CO_2 vehicles, bridges, catapults, syringe powered robotic arms, pens, wooden drink coasters and more.

i. Remove all jewelry, eliminate loose clothing, and confine long hair before using any machine.

ii. Open-toed shoes should not be permitted.

iii. Always wear appropriate PPE (safety glasses, ear plugs, dust masks, etc.) for the woodworking process being conducted.

iv. Equipment should be plugged into a GFCI outlet in case power is cut off during operation. This will prevent a machine from automatically turning back on when power resumes.

v. Do not operate any equipment unless it is in safe working condition and all guards are in place.

vi. Lift heavy lumber using your knees and not your back. Seek help for moving larger or heavier items.

vii. Wear gloves to protect from cuts or splinters. Use sandpaper to remove splinters or sharp ends beforehand.

viii. Inspect all wood for nails, staples, glue, or other foreign objects before cutting, drilling, etc.

ix. Securely clamp work pieces in a well mounted vise or using clamps. Wood can have sharp ends or become hot, making it difficult to hold by hand.

x. Use a backing board to support material when drilling.

xi. Always unplug a machine or shut off the breaker before changing any blade/cutters or performing any maintenance.

xii. Remove all chuck keys, wrenches, etc. before turning a machine on.

xiii. Keep the work area clean and organized as sawdust can be slippery on concrete or tile flooring.

xiv. Measurements and adjustments should be made when the machine is turned off.

xv. Keep hands at a safe distance from all blades, cutters, drill bits, etc. Use a sturdy push stick to feed material int the machine.

xvi. Do not sand or grind materials that produce harmful dust or debris (e.g., beryllium).

xvii. Turn on the vacuum, dust collection and/or air filtration system before turning on the machine. Inspect and change filers according to manufacturer specifications.

xviii. If a piece of wood gets stuck in a machine/blade/bit, immediately turn off the machine and wait for it to come to a complete stop before attempting to remove the work piece.

xix. Always wait for machines to come to a complete stop before walking away.

xx. Use caution when cleaning up wood scraps as they may be sharp. Never use compressed air to clean up sawdust or scraps.

xxi. When applying paint, stain, epoxy, fiberglass to wood be sure to do so in a well-ventilated area (e.g., paint booth) and wear PPE. Only use finishes that are designed for wood materials and do not combine items that should not be mixed according to the product label or SDS.

xxii. Properly dispose of any finishes and rags. Do not mix with other wood working scraps (e.g., saw dust and stain rags could combust in the same waste container).

xxiii. If a machine is out of order, make sure there is signage placed on it indicating it is not to be used and lock it out or remove the power switch insert so it cannot be turned on.

The following resources provide additional guidelines for woodworking tools and safety guidelines for specific woodworking equipment:

- OSHA Woodworking eTool
- Cornell University's Woodworking Machine Safety Toolbox Talk
- ITEEA's Safety Resources Website
- Virginia Tech's Laboratory Safety Resources

2. Metalworking Equipment

To produce metal products a number of extremely hazardous machines are needed such as horizontal band saws, drill presses, metal lathes, a furnace, soldering equipment, etc. Metal products produced could include simple electric motors, robotics, windmills, transportation devices, tin boats, metal sculpture and more.

a. Metalworking (Hot and Cold)

i. Remove all jewelry, eliminate loose clothing, and confine long hair before using any machine.

ii. Open-toed shoes should not be permitted.

iii. Always wear appropriate PPE (safety glasses, heat gloves, ear plugs, dust masks, etc.) for the metalworking process being conducted. When working with hot metal (e.g., forging) leather heat resistant gloves and an apron are required.

iv. Equipment should be plugged into a GFCI outlet in case power is cut off during operation. This will prevent a machine from automatically turning back on when power resumes.

v. Do not operate any equipment unless it is in safe working condition and all guards are in place.

vi. Lift heavy metal stock using your knees and not your back. Seek help for moving larger or heavier items.

vii. Use caution when handling metal stock and wear gloves to protect from sharp metal burs. Remove burs beforehand if possible.

viii. Securely clamp work pieces in a well mounted vise or using clamps because metal can be sharp and hot, making it difficult to hold by hand.

ix. Always unplug a machine or shut off the breaker before changing any blade/cutters or performing any maintenance.

x. Make sure all tools/blades/bits are sharp and in good working condition. Select the correct tool/blade/bit for the process to be performed and only use items that are designed for metalworking purposes.

xi. Remove all chuck keys, wrenches, etc. before turning a machine on.

xii. Center punch all holes before drilling.

xiii. Before drilling or cutting metal via a drill press or horizontal band saw, lubricate the cut area with cutting oil. When finished, thoroughly clean up and dispose of any spilled cutting fluids or rags.

xiv. Keep hands at a safe distance from all blades, cutters, grinding wheels, drill bits, etc., when appropriate, use a pair of vise grip pliers for a better grip and to maintain a safer distance from the hazard area.

xv. Remove metal scraps with a brush. Never use your hand or compressed air.

xvi. When sanding or grinding metal, sparks may be emitted. Conduct these activities away from other occupants and away from areas where sparks may combust. Do not sand or grind metals that will produce harmful dust or debris.

xvii. Never touch any hot metals or liquids. Use heat resistant gloves and vise grip pliers or tongs to handle metal pieces that were just forged, cut, sanded, etc. as they will be hot from the process.

xviii. Always wait for machines to come to a complete stop before walking away.

xix. When finishing metal be sure to do so in a well-ventilated area (e.g., paint booth) and wear PPE. Only use finishes that are designed for metal materials.

xx. If a machine is out of order, make sure there is signage placed on it indicating it is not to be used and lock it out or remove the power switch insert so it cannot be turned on.

b. Soldering

The Carnegie Mellon University Environmental Health and Safety: Soldering Safety Guidelines provide additional guidelines for soldering safety.

i. Always wear ANSI/ISEA Z87.1 D3 safety glasses or goggles in case of flux spatters.

ii. Wear heat resistant gloves when there is the potential to come in contact with hot surfaces.

iii. Do not touch the soldering iron or soldering parts until cool.

iv. Always return a hot soldering iron to its stand, never set on a table/workbench. When not in use unplug the soldering iron. Exercise caution to prevent a hot soldering iron from touching the power cord.

v. Conduct soldering activities under a fume hood or in a well-ventilated area away from combustible fumes. Bench top filtration systems can be used for rosin-free soldering activities.

vi. Use rosin and lead-free solders.

vii. Wires to be heated should be held with tweezers, pliers, or clamps to avoid burning fingers.

viii. Always wash hands with soap and water after soldering or handling soldering materials.

c. Casting and Molding Processes

i. Remove all jewelry, eliminate loose clothing, and confine long hair before conducting any casting or molding work.

ii. Open-toed shoes should not be permitted.

iii. Always wear appropriate PPE (face shield, heat resistant gloves, leather apron, leather sleeves, leather leggings with shoe protectors, etc.) for the casting or molding work being conducted.

iv. Keep the foundry area clean and clear of any combustible debris or fumes.

v. Use caution to not crush hands or limbs when ramming molds.

vi. Never leave a heat source (e.g., furnace) unattended when turned on.

vii. Do not pour molten metal into a plaster mold until you are certain all traces of moisture have been removed from the mold.

viii. Molds should be clamped down/together to prevent floating when metal is poured.

ix. Keep a safe distance between hands or limbs and the heating source. Always use proper PPE (heat resistant gloves, steel tongs, etc.) when working near the heat source or handling parts form it.

x. Do not attempt to add cold or additional metal into already molten metal. This could result in splashing and severe burns.

xi. Do not allow water to come in contact with molten metal. This will result in an explosive reaction.

xii. Do not pour castings on concrete, any spilt molten metal will splash. Pour castings within a dry sand pit.

xiii. Never stand directly in front of a mold when pouring. Steam could be generated causing burns, or if a mold is too moist the molten metal could spurt from the mold.

xiv. Carefully place hot castings or molds in a heat resistant are to cool. Display a sign to indicate they are hot.

xv. Never attempt to open or touch molds before proper curing and cooling is complete.

The following resources provide additional guidelines for metalworking equipment:

- OSHA Welding, Cutting Brazing
- Cornell University's Hot Work Toolbox Talk
- Virginia Tech's Laboratory Safety Resources

3. Plastics Equipment

To produce plastic products a number of extremely hazardous machines are needed such as injection molders, vacuum formers, rotational molders, acrylic strip heaters, etc. Plastic products produced could include plastic boats, miniature car wheels and bodies, tool handles, food molds and more.

a. Remove all jewelry, eliminate loose clothing, and confine long hair before conducting any plastics work.

b. Open-toed shoes should not be permitted.

c. Always wear appropriate PPE (safety glasses, heat resistant gloves, leather apron, etc.) for the plastics work being conducted.

d. Keep the plastics work area clean and clear of any combustible debris or fumes.

e. Wear gloves to protect from sharp edges. Use sandpaper to remove sharp edges beforehand.

f. Securely store plastic materials and supervise students to avoid misuse (eating or throwing of plastic beads, etc.).

g. Use caution to not crush hands or limbs in any extruding mechanisms.

h. Never leave a heat source (injection molder, vacuum former, etc.) unattended when turned on.

i. If using molds, they should be tightly clamped together.

j. Keep a safe distance between hands or limbs and the heating source. Always use proper PPE (heat resistant gloves, steel tongs, etc.) when working near the heat source or handling parts form it.

k. Do not overheat plastic as it is flammable.

l. Exercise caution when melting and forming plastic. Plastic can liquify and drip, causing severe burns.

m. Carefully allow hot molds and patterns to cool before removing the desired plastic product(s).

n. When sanding or cutting plastic do so in a well-ventilated area (e.g., connected to a dust collector) and wear PPE (Safety glasses, respirator, etc.).

o. Use caution when handling plastics that were just cut or sanded as they could be hot and sharp.

p. Securely clamp work pieces in a well mounted vise or using clamps because plastic can be difficult to hold by hand when drilling or cutting.

q. Remove plastic scraps with a brush. Never use your hand or compressed air.

r. Make sure that there is appropriate ventilation when working with plastics. Some forms can be toxic and flammable.

s. If a machine is out of order, make sure there is signage placed on it indicating it is not to be used and lock it out or remove the power switch insert so it cannot be turned on.

4. 3D Printers

3D printing technology has become more affordable in recent years. It can potentially pose a health risk because of its potential to release volatile organic chemicals (VOCs) and ultrafine particles (UFPs) into the air during operation. This could affect indoor air quality and may expose people to pollutants that may lead to adverse acute and chronic health concerns depending on the technology used in the classroom/laboratory and the HVAC on site.

a. Always were sanitized safety glasses or goggles when observing the 3D printer, removing items or support materials from the printer.

b. Use 3D printers that can print PLA. Use PLA and not ABS in the printer whenever possible. PLA is made from cornstarch, is biodegradable and is considered safer.

c. Use filaments that are specifically recommended by the manufacturer for the 3D printer.

d. Use 3D printers and filaments that have been tested and verified to have low chemical and particle emissions.

e. If the 3D printer is an enclosed model, the door should remain closed during the printing process.

f. Non-enclosed 3D printers without a built-in ventilation system should be operated under exhaust ventilation fume hoods or spray booths.

g. Ensure the 3D printers are used in well-ventilated areas. Have an air quality analysis of the area where the 3D printers will be operating to ensure proper air-changes-per-hour (ACH) rates. Research recommends an ACH of at least 3 volumes of the room per hour. An appropriate portable electrostatic air filter can help with the ACH rate for 3D printers as well as dust and other airborne particles.

h. Air filtration systems should always be turned on and functioning properly when 3D printers are in use. Ensure that filters are changed according to manufacturer specifications.

i. Keep students from standing beside or hovering over a 3D printer while it is in operation.

j. Set the printer nozzle temperature to the lower end of the suggested temperature range.

k. Do not touch the printer head or reach into the 3D printer until it has cooled down.

l. Never reach inside of a 3D printer while it is operating.

m. Follow all hand tool safety procedures if using a scraper, putty knife, pliers, etc. to remove support materials.

n. If using acids to remove support materials or chemicals to smooth the final product, follow all manufacturer and SDS guidelines for the use and storage of the acids and chemicals. Use appropriate PPE when working with these chemicals. See Chapter 7, Chemical Management, Handling and Disposal.

The following resources provides additional 3D printer safety information:

- ITEEA Safety Resources: 3D printers and Library Maker Spaces
- Rochester Institute of Technology: 3D Printer Safety
- NIOSH Nanotechnology Research Center: 3D Printing with Filaments: Health and Safety Questions to Ask

5. Textiles Equipment

Textiles can be one of the cheapest and least hazardous materials to work with compared to wood, metal, and plastics. Working with textiles can include hazards such as fabric dyes, needles, heat, steam burns, etc. Projects that use textiles include apparel, 3D printing on fabric, smart clothing, origami, pencil holders, bean bags for games, pillows, furniture upholstery and more.

a. Remove all jewelry, eliminate loose clothing, and confine long hair before conducting any plastics work.

b. Open-toed shoes should not be permitted.

c. Always wear appropriate PPE (safety glasses, heat resistant gloves, leather apron, etc.) for the textile work being conducted.

d. Never place pins or needles in your mouth, in garments, or other places. Use a pin cushion. Throw away any bent pins or needles.

e. Hold scissors and shears blade down. Pass them by the handle. When transporting/carrying scissors and shears hold them by the closed blade end.

f. Never touch a hot iron or hot surface! Use a piece of scrap fabric to test the proper temperature.

g. Never leave an iron unattended when turned on. Always keep an iron on the heal when not in use.

h. Switch all equipment off when not in use. Unplug equipment and wait for it to cool down before making any adjustments or unjamming material/thread.

i. Never use irons, heating sources or electrical textile equipment near water or when hands are wet. Unplug an iron before adding water and do not overfill.

j. Use the correct heat setting for the material being ironed and be careful not to burn items.

k. A ceramic or heat resistant pad should be used for safer operation of items that may burn the work surface (e.g., iron).

l. Only one person at a time may use a textile machine, iron station, etc.

m. Use a thimble when doing hand sewing.

n. Keep hands a safe distance from heat sources, and the needle and presser foot of a sewing machine.

o. Do not operate a sewing machine with a bent or broken needle.

p. Conduct all sewing machine operations at a controllable pace.

q. Do not place foot on the sewing machine foot control until ready to sew.

r. Do not sew over pins, pull them out as you go to prevent the needle from hitting them.

D. SOUND HAZARDS

Power tools and machinery can produce high decibel levels during their use. Limited exposure may not be detrimental to a student's hearing but teachers who spend the entire day in this environment could potentially cause hearing damage. Prolonged exposure to sound in excess of 85 decibels (dBA) can result in permanent hearing loss of specific frequencies. OSHA (29 CFR 1910.95) mandates implementing a hearing conservation program for employees who are exposed to levels of 85 dBA or greater for 8 hours.

An effective hearing conservation program should include:

- Noise sampling in the areas using tools and machinery, including personal noise monitoring, which identifies employees and students at risk from hazardous noise levels.
- Informing students, parents/guardians, and teachers of the noise monitoring results.
- Maintaining records of instructor hearing tests.
- Implementing comprehensive hearing protection follow-up procedures for teachers who exhibit a loss of hearing after completing baseline and yearly audiometric testing.
- Proper selection of hearing protection (earmuffs, ear plugs, etc.).
- Training and information that ensures teachers and students are aware of the hazards from excessive noise exposures and how to effectively use PPE.
- Data management of, and teacher and parent/guardian access to, records regarding monitoring and noise sampling.
- Consideration of sound attenuation equipment and materials (e.g., acoustical tiles, sound absorbing panels, etc.) to reduce sound levels in the instructional space.

For more information on developing a Hearing Conservation Program visit Cornell University's Noise and Hearing Conservation website.

E. UNMANNED AERIAL SYSTEMS

Unmanned aerial systems (UAS) can be extremely dangerous because of their rotating parts, their propulsion source, and because they can be difficult to control once launched. There are a number of names for these types of objects in flight, but they can be classified into three basic categories:

- Multi-rotor – Multiple rotating propellers using microelectronics for stability and control. Usually powered by battery and electricity. They typically require the simplest piloting skills (ex. drones).
- Fixed wing – Can use electricity or combustion motors for propulsion or to drive propellors. More complex piloting skills needed (ex. model planes, rocket, gliders).

- Helicopter – The most complex in terms of parts and piloting. Can have propellors moving in multiple axis (ex. remote control helicopter)

Before doing any type of flight activity check with the school system policy regarding launching of aerial systems. The FAA also provides specific criteria for operating UAS in 14 CRF Part 107 of their Federal Aviation Regulations (FAR). Some schools may be in restricted airspace which could result in serious legal consequences. FAA regulations also require UASs over a certain weight to be registered. In some cases, they also require the operator to be 16 years of age and have earned a Remote Pilot Certificate with a small UAS rating.

1. **Preflight Preparations**

   a. Conduct a hazards inventory to assess all potential risks.

   b. Use a checklist of flight procedures and rehearse these procedures with a safer practice activity prior to the actual launch.

   c. Establish callouts/terms and hand signals to be used to communicate throughout various phases of the flight activity.

   d. Establish and identify safety zones that are a safe distance (minimum 10 feet) from the activity where students can watch while wearing appropriate PPE (ex. safety glasses).

   e. Brief the flight operation by clearly defining each participant's roles and responsibilities. Flight approval should receive unanimous approval from all participants.

   f. Inspect all UASs for properly attached and functioning parts prior to launch.

   g. Apply sterile cockpit rules for operators. Do not allow operators to become distracted with non-flight related discussions as pilot error accounts for most accidents.

   h. Develop a list of emergency procedures in case there is a crash, or an object does not fly as well as planned. Conduct safety drills to allow students to practice what they would do in the event of an accident.

   i. After the flight activity is finished and the UAS has returned to a safer state conduct a debrief activity to summarize what was learned.

2. **Indoor Flight Activities**

   a. All participants and observers must wear safety glasses or goggles.

   b. Ensure that UAS are tethered to a sturdy object.

   c. Attach blade guards that will not affect flight quality.

   d. Use only nano, micro, or mini drones for indoor flight.

e. Ensure that observers, participants, or obstacles (furniture, light fixtures, wiring, etc.) are not in the flight path.

f. Conduct a preflight inspection of the UAS with the battery/ignition/power source disconnected.

g. Conduct a function test of all controls prior to takeoff.

h. Conduct a review of safety procedures with observers prior to the flight.

j. Fly only one UAS aircraft at a time.

3. Outdoor Flight Activities

a. All participants and observers must wear safety glasses or goggles.

b. Meet all operator and UAS requirements and obligations applicable to the UAS and its specific use as required by the FAA.

c. Maintain documentation that certifies that the operator has been trained in the proper and safer use of the UAS.

d. Inspect the flight area to ensure there are no previously unnoticed hazards (power lines, trees, debris near the launch site, etc.).

e. Flights are safer over open, clear, unoccupied areas.

f. Do not launch UAS during adverse weather conditions (high winds, rain, etc.).

g. A SDS must be kept on file for any fuels used in the UAS.

h. Fuels should be stored according to SDS recommendations and in a locked flammable proof cabinet.

F. EMERGENCIES

Working in spaces with tools and machinery, a teacher can sometimes be in the position of first responder where they might need to provide basic first aid. Chapter 5.C, Response to Injuries covers general procedures for typical injuries related to a normal science classroom. This section identifies emergencies associated with the use of tools and machinery. Teachers and school officials should be properly trained to initiate initial first aid before trained medical professionals arrive. Below are possible injuries.

1. *Penetrating Objects*. Do not attempt to remove the object. Keep the student calm and still. Request immediate assistance from the school health provider or 911.

2. *Shock*. Lay the student down and elevate legs and feet slightly unless this will cause additional injury. Keep the person still and do not move. Loosen tight fitting clothing if necessary and over with a blanket to prevent chilling. Do not let the students eat or drink anything. If the student

vomits or is bleeding from the mouth, turn them onto their side unless a spinal injury is suspected.

3. *Heatstroke*. Move the student out of the heat immediately. Remove any PPE that might prevent body heat from dissipating (heat resistant gloves, leather apron, leather sleeves, leather leggings with shoe protectors, etc.). Cool the student down by using the safety shower, fanning while misting with cool water, placing ice packs or cool wet towels on the neck and armpits. If the student is conscious offer chilled water, a sport drink, or other beverage without caffeine.

4. *Amputation*. Request immediate assistance from the school health provider and call 911. After putting on a pair of gloves, stop the bleeding by applying direct pressure to the wound. If there is an object in the wound apply pressure around it, not directly over it. Have the student lay down and elevate the site that is bleeding. Keep the wound clean. Treat for shock if needed. Recover the amputated body part, if possible, and transport it to the hospital with the injured student. Gently rinse off dirt with clean water, do not scrub. Wrap the amputated part in dry sterile gauze or clean cloth. Put the wrapped part in a plastic bag and place the bag on ice. Do not cover the part with ice or put it directly into ice water.

Chapter 13: Virtual and Remote Science Learning

Based on research, students learn science most effectively by doing science, including asking questions, conducting investigations, and drawing conclusions. Having these experiences remotely or virtually outside the science laboratory is not ideal but is not always avoidable. Technology access and availability have led to an increase in virtual schools and virtual instructional days due to severe weather, pandemic, or natural disasters. School systems need to have policies and protocols in place to handle the expectations of learning science virtually or in remote learning situations. Teachers, supervisors, and administrators need to address safety issues and essential components of science activities given in these situations. NSTA has released several white papers, *Safer Remote Instructional Guide for Elementary School Science* and *Safer Remote Instructional Guide for Science Grade Levels 6–12*, that can be referenced for more information about this topic.

This chapter is meant as a guide to provide an additional level of safety review to ensure safer practices are being implemented for at home science; each school system may have its own policies that must be followed. At no time should a teacher assign a laboratory for students to compete at home that does not follow the guidelines and policies set forth by their school system.

A. RESPONSIBILITIES

1. Science Supervisors

a. Should meet with their departments/teachers to discuss any at-home investigations to be assigned, the equipment needed, and the procedures that students will be expected to perform.

b. Should work with their department/teachers to brainstorm potential problems with the at-home investigations so they can warn students and parents/guardians about them before any investigation takes place.

c. Should require teachers to do a thorough hazard analysis and risk assessment, reviewing all procedures and equipment needed prior to assigning any investigation for students to do at home. If any safety hazard with potential resulting risk is foreseen that cannot be addressed through safety actions (e.g., engineering controls, operating procedures, and/or personal protective equipment [PPE]), the investigation should not be done outside the school building.

d. Should ensure that students are always given alternative assignments that they can do without penalty or embarrassment if carrying out an investigation is impossible.

2. Teachers

a. Must provide an at-home science safety agreement for students and parents/guardians to sign and return. No investigations should be done until the safety agreement has been signed and returned. Provide agreements in the student's native language if possible. Sample agreements are posted on the NSTA website.

b. The safety agreement should include a disclaimer statement, which includes at least the following:

i. "Students must conduct all activities under adult supervision."

ii. "Using alternative materials or procedures for these activities at home may jeopardize the level of safety and therefore is at the user's own risk."

iii. "Do not hesitate to contact your instructor if in doubt of any safety protocols."

c. In their lesson plan, teachers should include the standards to be addressed by any investigations or projects that will take place.

d. Opportunities for students to ask questions prior to performing the activity should be required.

e. Any activity techniques that may be required should be demonstrated prior to performing the activity. It is recommended that the teacher upload a short video clip to their learning management system that describes and demonstrates the activity's techniques for students and parents/guardians.

3. Parents/Guardians

a. Should read and sign the appropriate safety acknowledgment form and the disclaimer statement before their child begins any at-home investigations.

b. Should view the entire lesson/handout and any videos that the teacher provides of the setup of an investigation to ensure that they thoroughly understand what their child is being asked to do.

c. Parents/guardians who are uncomfortable with or unable to perform the investigation should notify the teacher and request an alternative assignment.

d. Should discuss any disabilities their child has with the teacher so the teacher will be aware of modifications needed to allow the student to gain the most benefit from the assignment.

4. Students

a. Must read and sign the appropriate safety acknowledgement form and disclaimer statement provided by the teacher.

b. Must read carefully any written instructions provided by their teacher before they begin the investigation.

c. Should only perform the investigation assigned by the teacher.

d. Should not begin any investigation without supervision by an adult.

e. Should wash their hands each time they walk away from the investigation.

B. GUIDELINES

1. All investigations should be conducted under the supervision of an adult.
2. When appropriate substitute virtual laboratory (PhET, HHMI, Concord Consortium, Labster, Gizmo, etc.) and teacher-led demonstration activities for at home activities.
3. Work that students will perform at home must not require special ventilation. Activities that would normally be performed in a fume hood should not be done outside of the school building.

4. Investigations performed at home should not require students to provide the PPE. The school system should provide the necessary PPE to the student. If the school system does not provide the PPE, then the investigation should not be performed at home.

5. All lab items provided to the students, especially PPE, should be cleaned and sanitized by the teacher or school system before distributing and also upon receipt from students.

6. Investigations that generate hazardous waste should not be done at home. Chemical waste may not be poured down the drain!

7. Proper disposal considerations should be provided during instruction or made available for students. All proper or pertinent waste and disposal procedures should follow local and state regulations put forth by the SDS.

8. Infectious materials may not be used at home. This includes human materials.

9. Consider allergens. Activities involving food should include alternatives for students with food allergies. If materials sent to students contain such items as latex balloons, make sure these items are not included in the materials provided to students with latex allergies.

10. Remember that students will not be working in a controlled laboratory environment. Their homes may include small children, pets, or family members with respiratory sensitivities and allergies. Modifying materials sent home for allergens of household members must also be considered.

11. Paints and other supplies used should be marked with the ASTM Non-Toxic label. All liquids sent home to the student should be clearly labeled and in sealed containers. No hazardous chemicals should be sent home!

12. SDS sheets accompanying any investigation materials should be included with the items sent home and provided in advance for parents/guardians or the supervising adult to review.

13. Directions for proper storage of liquids or other materials (as specified on the SDS) sent home must also be provided by the teacher to the parents/guardians or the supervising adult (ex. Store in a closed cabinet out of reach of pets or small children, etc.).

C. VIDEO DEMONSTRATIONS

An alternative to at home science investigations is for students to view demonstration videos. These videos might be created by the teacher or found online. Videos should provide closed captions for students with disabilities or captions in the student’s native language if possible. Safety considerations should also be applied to any video used instructionally during virtual or remote learning. Although verbiage, like “do not try this at home” may be used to deter students from attempting something, better legal safety standards and professional practices are expected.

1. **Videos should:**

    a. occur in the proper science facilities. They should not occur in kitchens or homes.

    b. emphasize and demonstrate appropriate safety precautions throughout the virtual session or video demonstration.

    c. comply with all state and local fire, health, and safety rules and regulations.

d. demonstrate the use of personal protective equipment such as eye protection, aprons, gloves, and safety equipment for participants who handle chemicals or hazardous substances or working with flames.

e. use a safety barrier when physical, biological, and chemical hazards exist. For example, provide a machine guard when motor-driven discs are revolved at moderate or high speeds and move participants to a safer distance from the rotating disc.

f. warn viewer about when loud controlled explosion is anticipated, and alert them at the beginning of the video about the presence or production of allergenic materials during the demonstration.

g. follow proper procedures for working with pressurized gases and when heating all forms of matter.

2. Videos should NOT:

a. depict tasting or directly smelling any chemicals or substances used in the video.

b. dump or dispose of any hazardous liquid, solid, organic, or recyclable waste in an inappropriate manner.

c. show lasers shining directly into the eyes of an observer or from a reflected surface into the eye.

d. show the direct viewing of the Sun or of infrared or ultraviolet sources.

e. contain activities that endanger parts of the body, such as placing dry ice in the mouth, dipping hands into liquid nitrogen, exposing the hands and face to microorganisms, walking on broken glass or hot coals with bare feet, or lying on a bed of nails.

f. use live ammunition, firearms, commercially available fireworks, and blasting caps.

h. involve dangerous explosives, such as benzoyl peroxide, diethyl ether, perchloric acid, picric acid, and sodium azide.

i. involve volatile toxic substances, such as benzene, carbon tetrachloride, and formaldehyde.

j. contain activities that could result in the release of harmful quantities of noxious gases into the local air supply.

k. contain activities that involve plants with poisonous oils (e.g., poison ivy) or saps (e.g., oleander), and other plants known to be toxic to humans.

l. involves the use of human or animal blood / body fluids or other potentially infectious materials (OPIMs).

m. include demonstrations or investigations using live vertebrate animals. See Chapter 9.D, Zoology: Animal Considerations for more guidance.

n. include the flying of drones or other types of unmanned aircraft or rockets without following the proper safety procedures for their use. See Chapter 12.E, Unmanned Arial Systems and Chapter 11.H, Rocketry for more guidance.

Chapter 14: Safety in the Elementary Classroom

This chapter provides information to assist the elementary school staff in maintaining a safe classroom environment for the teaching of science. Safety is an important concern in the elementary science classroom because students are learning new skills and working with unfamiliar equipment and materials that can pose some degree of hazard. Safety in the elementary school science classroom depends on the wise selection of experiments, materials, resources, and field experiences as well as consistent adherence to correct and safe techniques. This chapter should be reviewed carefully to avoid accidents.

Safety in the science classroom requires thorough planning, careful management, and constant monitoring of student activities. Teachers should be knowledgeable of the properties, hazards, and proper use and disposal of all materials used in the classroom. This information is available through Safety Data Sheets (SDSs). Federal law requires that vendors of laboratory chemicals provide an SDS for each substance they sell. The sheets provide detailed information about the physical and chemical properties, proper storage, disposal, toxicology, etc., of substances. The law also requires that SDSs be available at the worksite. See Appendix C, Hazard Communications Standard.

Anticipating, recognizing, controlling, and eliminating hazards require knowledge and understanding of safety issues discussed in this safety manual. The information provided in the manual is intended to help teachers present stimulating science lessons in the safest learning environment possible. If more information is needed on any specific topic, please see the appropriate chapters for more details.

A. TEACHER RESPONSIBILITIES

Safe laboratory programs require participation by administrators, teachers, students, and the community. Administrators need to make available a laboratory area for science activities that is functional and safe. Teachers need to set a good example by being enthusiastic about safety.

Teachers maintain a safe science program by exercising good judgment, providing proper instruction and supervision, and maintaining a written record of safety instruction. Teachers ensure that all students, including multilingual learners and those with disabilities, can participate fully and safely in the science classroom. Students are expected to follow all safety procedures and rules in the safety rules agreement that they have signed. Also, students need to follow all additional instructions their teachers give them concerning the laboratory exercises they perform. The safety rules agreement must also be read and signed by parents/guardians, thus ensuring that parents/guardians know and support the goal of safety in the science classroom. See Chapter 1, Responsibilities for specific roles and responsibilities.

B. LEGAL ASPECTS

When working in the elementary science classroom, the safety of the classroom occupants is of the utmost importance. It is in the best interest of all parties for the elementary classroom teacher to take proactive measures, including:

- exercising good judgment in planning, conducting, and supervising instruction,
- maintaining laboratory and safety equipment necessary to carry out instruction safely, and
- documenting that appropriate safety instruction has taken place.

Additionally, best practices include:

1. provides prior warning of any hazards associated with an activity.
2. demonstrates the essential portions of the activity.
3. provides active supervision.
4. provides sufficient instruction to make the activity and its risks understandable to all students, including multilingual learners and those with disabilities.
5. ensures that all necessary safety equipment is available and in good working order.
6. has sufficient training and equipment available to handle an emergency.
7. ensures that the place of the activity is as safe as reasonably possible.

Teachers must also be aware of the requirements under the Individuals with Disabilities Education Act (IDEA) and Section 504 of the Rehabilitation Act. A student's Individual Education Program (IEP) or Section 504 plan will outline the accommodations and/or modifications necessary for a student to receive access to and make progress in the curriculum. This includes the same access to the grade-level science curriculum and experiences as a student's non-disabled peers. The Disabilities, Opportunities, Internetworking, and Technology (DO-IT) publication *Making Science Labs Accessible to Students with Disabilities* is a good guide to ensuring that students with disabilities receive the appropriate science experience.

See Chapter 2, Legal Aspects of Laboratory Safety for more information.

C. SAFETY CONCERNS AND SAFETY EQUIPMENT

Classroom size is a major concern when conducting science activities. There must be a reasonable amount of space for each student and for safety equipment and storage facilities.

A safety plan and first aid kit should be in every science classroom. Emergency procedures and phone numbers must be readily available. Materials, storage space, and evacuation routes must be clearly marked. Ensure that all signs and labels are in any language spoken by the students using the science classroom. Teachers need to know the location and proper use of gas and electric cut-offs.

Proper maintenance of safety equipment is essential. Teachers need to know the location and proper use of equipment such as fire extinguishers, fire blankets, and eyewash fountains or devices. The use of safety goggles is required for many science activities. Teachers should also be aware of the need for special or more specific safety aids such as spill kits, safety shields, safety showers and the ability to provide adequate room ventilation during science activities.

In the event of a fire remember that the personal safety of the building's occupants must always be the first priority. The teacher should know the location and how to use the nearest fire alarm box, as well as follow school system procedures for use of (or direction of emergency personnel to use) any fire extinguishers, fire blankets, or other firefighting aids that may have available in the classroom. If a person's clothing or hair catches on fire, have the person stop, drop, and roll on the floor to suffocate the flame or use a safety shower. Do not use fire extinguishers on people.

Safe science classrooms have:

- the availability and, when necessary, the wearing of aprons and gloves.
- care in preventing loose clothing or long hair from becoming a hazard.
- special attention to prevent eye damage by wearing appropriate goggles.
- adequate workspace for students and teachers.
- clearly marked emergency evacuation routes.
- master gas and electric cutoffs.
- hand washing stations available.
- properly maintained safety equipment.
- signs and labels to identify safety.

See Chapter 3, Safety Concerns and Safety Equipment for more information about specific safety equipment as needed.

D. PERSONAL PROTECTIVE EQUIPMENT (PPE)

Providing a safe laboratory environment involves a combination of many efforts. In addition to proper training, procedures, ventilation, and emergency equipment, it is important to provide teachers and students with proper personal protective equipment (PPE).

1. Eye Protection

a. Safety Goggles

Md. Code, Education §7-407 requires the use of industrial quality eye protective device for teachers and students while working in a laboratory that involves caustic or explosive chemical or hot liquid or solid. Use chemical splash safety goggles when engaged in any activities that might pose a risk of eye injury. Safety goggles should be used when:

- using laboratory chemicals in an activity.
- using projectiles or sharp objects.
- flying particles are likely to be produced (as when solid materials are struck).
- when heating materials.

Elementary schools may purchase one or more sets of safety goggles to be kept in the school and shared among all teachers. They would be stored with other science equipment. The goggles must be cleaned after each use. There are several ways to clean goggles. If funds allow, an ultraviolet cabinet can be used to store and sterilize the goggles. Alternatively, single-use alcohol wipes can be used to clean all surfaces including the strap. Another alternative is to dip the goggles in a dilute solution of bleach and allow to air dry. See Chapter 4.A, Eye Protection for more details on safety goggles and how to clean them.

b. Group Demonstrations

For group demonstrations, use a safety shield (clear, chemical and impact-resistant plastic) to provide additional safety. If a safety shield is not available, all individuals present in the classroom should where the appropriate PPE and be a safe distance from the investigation.

c. Eye Safety Planning

To ensure an effective program of eye safety, teachers should:

- establish a plan for storage, cleaning, and distribution of goggles;
- discuss with students the need for and appropriate use of safety goggles;
- discuss the need for eye safety when planning science activities; and
- provide eye protection for everyone performing or observing laboratory activities when there is a risk of a hazard to the eyes.

2. Gloves

Gloves should be worn whenever it is necessary to handle corrosive materials, rough or sharp-edged objects, extremely hot or very cold materials, or whenever protection is needed against accidental exposure to chemicals.

a. Consider student allergies to latex when using gloves. Non-latex gloves are the best option for use in the science classroom.

b. Students should wash their hands immediately after removing gloves.

3. Aprons/lab coats

Aprons and laboratory coats are intended to prevent contact with contaminants and the minor chemical splashes or spills encountered in a science activity. The cloth laboratory coat is, however, primarily a protection for clothing and may itself present a hazard (e.g., combustibility) to the wearer.

See Chapter 4, Personal Protective Equipment for more information.

E. SAFETY STRATEGIES IN AN ELEMENTARY CLASSROOM

Safety strategies are essential when dealing with students and science activities. In planning and setting up science activities, it is essential to consider safety issues. Before the activity teachers should ensure that all students, including multilingual learners and those with disabilities, can safely and effectively engage in safe science procedures by providing clear, accessible, and inclusive instructions. During the activity, teachers should move about the room or area where the students are working. They must be familiar with the materials, equipment and procedures that are part of the activity. Access to materials and equipment having the potential for harm or misuse (e.g., chemicals, heat sources, sharp objects) must be controlled.

Teachers make science classrooms safe by:

- teaching all students, including multilingual learners and those with disabilities, how to conduct science activities safely.
- making sure that safety equipment is functioning and readily available.
- being a model for obeying safety rules.
- supervising students to ensure that they obey safety rules.
- documenting safety instruction.

Students make science classrooms safe by:

- not engaging in horseplay or other acts of carelessness.
- following the instructions for the science activity.
- asking the teacher to explain the instructions if they are not clear.
- never eating or drinking during a science activity.
- notifying the teacher of any dangerous situations in the classroom.
- reporting all accidents, no matter how minor, to the teacher immediately.
- knowing the location of safety and first aid equipment, including goggles, gloves, safety shower, and eye wash.
- washing hands after all spills and at the end of each science activity.

See Chapter 5, Safety Strategies in the Classroom for more information.

F. SAFE HANDLING OF EQUIPMENT

The safe handling and use of materials and equipment should be foremost in the minds of teachers. This section provides guidelines for the safe handling and use of a variety of equipment encountered in an educational setting.

Teachers and students avoid accidents by:

- using the proper equipment.
- making sure the equipment is clean and in good working order.
- receiving instructions on the proper use of all equipment.
- practicing proper use of equipment.

Teachers and students must be aware of the potential hazards associated with glass and other sharp objects, hot materials or objects, ingestion of harmful chemicals, and electricity.

1. **Glassware**

   Substitute plastic labware for glassware where possible. New plastics like polycarbonate (Lexan®) have been successfully used for laboratory containers. While not useful for heating, the plastic is clear and extremely hard and can be used for almost all water-soluble compounds. Beakers, flasks, graduated cylinders, and thermometers are now available in plastic. Check with your science supply company.

   Effective Safety Practices with use of glassware:

   - Always inspect glassware for chips or cracks before and after use. Cracks will eventually work their way through the glass. Discard any cracked item.
   - Glassware that is to be heated should be made of borosilicate glass (e.g., Pyrex® or Kimax®).
   - Remember that hot glass and cold glass look exactly the same.
   - Never place heated glass items near students.
   - Never place heated glass items in water.
   - Do not use glassware designed for science experiments as a container for consumable liquids and materials.

2. **Electrical Devices**

   Effective Safety Practices for electrical devices:

   - Electrical devices used in the science classroom must have a three-prong (grounded) plug. The third wire grounds the metal housing on the device. If you have to use a plug adapter, make sure it is properly grounded.
   - Electrical plugs should not be modified in any way.
   - Remind students to remove an electrical plug from a receptacle by pulling the plug, not the cord.

- Students should be warned/reminded never to put any object into an electrical outlet. Teachers may want to cover unused outlets with plastic inserts to safeguard against this risk.
- Do not use devices with cords that are frayed and/or cracked. This condition can lead to electrical short circuits that can cause burns and/or fires.
- Electrical cords on the floor or draped across desks create tripping hazards.

3. Heat Sources

Where possible, use electric hot plates in place of gas burners (Bunsen, portable propane, and butane). *Alcohol burners should never be used as a heat source.*

Effective Safety Practices for heat sources:

- Always wear goggles when heating any solid or liquid.
- Never leave anything unattended while it is being heated or is reacting rapidly.
- Never heat a closed container.
- Any set-up should be designed to allow for fast removal of the heat source.
- Only solid metal or glass-top hot plates with on/off indicator lights are recommended.
- Hot plates should be handled with particular care since there is no difference in the appearance of one that is on and one that is off.

4. Thermometers

Thermometers being used in the classroom must be alcohol filled. Md. Code, Environment §6-906 prohibits the use or purchase of elemental or chemical mercury in primary or secondary classrooms, which includes mercury filled thermometers. If a mercury thermometer is located in a school, it should immediately be removed from student access and properly disposed of by the school system.

Effective Safety Practices for thermometers:

- Never use a thermometer as a stirring device.
- Never swing or shake down a thermometer.
- Never use an open flame on a thermometer bulb.
- Do not place thermometers where they are likely to roll or be knocked off a table. All thermometers should have anti-roll devices.
- Make sure you choose a thermometer with an appropriate temperature range. Overheating a thermometer can cause breakage of its reservoir.

5. Batteries

There are two main types of batteries: dry cell and wet cell batteries. Dry cell batteries include single use alkaline batteries and rechargeable (lithium-ion or nickel-cadmium) batteries. Wet cell batteries contain a liquid like car or boat batteries. Batteries come in a variety of voltages and sizes. Any battery can generate heat and cause burns to the skin when a wire is placed across both terminals. Battery use in the science classroom must be supervised. Rechargeable and wet cell batteries should be properly recycled or disposed of; they should not be thrown in the regular trash like single use alkaline batteries.

See Chapter 6, Safe Handling of Equipment for more information.

G. MANAGEMENT, HANDLING, AND DISPOSING OF CHEMICALS

Ordering, storing, the relative hazard level of the chemical, and disposing of chemicals are important procedures that, when properly handled, contribute to a safe science classroom. Therefore, all teachers of science need to understand these procedures. Chemical safety begins with the teacher who orders and uses these products. A teacher considering ordering a chemical for elementary science classroom use must understand the educational value of using it, their own familiarity with the chemical, and whether the classroom is adequately equipped for the use of the chemical.

Laboratory chemicals pose a potential hazard in the elementary science classroom. Most elementary school teachers are not formally trained in chemistry, yet chemicals are sometimes used in their science programs. Many laboratory chemicals have common names that may cause confusion in identifying safety hazards.

1. Chemical Hygiene Plan

The Laboratory Standard instituted by OSHA requires school systems to appoint a chemical hygiene officer to develop, implement, and monitor a chemical hygiene plan (CHP). Each school in the school system might also need to develop its own CHP and identify a chemical hygiene officer for that building. The chemicals involved in the CHP go beyond just those found in the science classroom and includes other chemicals in the building like art supplies, cleaning supplies and materials used in completer or CTE programs. The use and disposal of chemicals in the school and school system should be regulated by the CHP.

2. Chemical Safety Practices

a. Chemical Labeling

- Label all containers with the substance's common name, hazard precautions (GHS), date, and storage area. For each substance, teachers should have available the information listed on the SDS form.
- Most elementary "kits" use prepackaged and lesser amounts of chemicals. These packages may have only the substance name and weight. Chemicals purchased

from major chemical supply companies may have sufficient information on the label (safety warnings and precautions).

- Teachers should not set out the entire container of a material; they should estimate the amount to be used and place it in a labeled container.
- After the laboratory investigation, the remaining material in the container should be properly disposed of and not placed back in the stock bottle.
- Substances that have no label and are unidentified should be carefully disposed of in an approved manner.

b. Chemical Storage

- Storage areas and containers should be labeled.
- Access to these storage areas should be limited so that students cannot remove substances from them.
- Laboratory chemicals should be stored in a cool, well-ventilated room with shelving spacious enough to maintain separation of incompatible substances.
- Flammable liquids should be stored in standard safety cans placed in a metal cabinet.
- Store dry chemicals above liquids, and store oxidizers away from all other chemicals.
- When transporting chemicals from the storage area to the classroom, use a cart with shelves that have raised edges.
- Do not allow children to transport hazardous substances.

See Chapter 7.B, Managing Chemicals for more information.

3. Substances Too Hazardous for Elementary Schools

The following substances should not be used in the classroom because they present too great a safety hazard.

a. Strong acids. Strong Acids such as hydrochloric, sulfuric, or nitric acid should not be used. Even “dilute” solutions of these acids can cause skin and eye burns.

  i. Two acids safe to use are vinegar (weak acetic acid) or a weak citric acid solution.

  ii. When working with acids, always wear chemical splash safety goggles.

b. Asbestos. Asbestos should not be used and if found, should be discarded according to school system policy. Some forms of this mineral – commonly used in heat-proofing applications – are known to cause cancer.

c. Strong Bases. Sodium hydroxide (lye) or potassium hydroxide are extremely strong bases. Even dilute solutions will irritate the skin and, if splashed in the eyes, may cause injury before one can begin to wash the eye out. For acid-base (pH) activities, the teacher should consider sodium bicarbonate (baking soda) when making a basic solution. When working with bases, always wear chemical splash safety goggles.

d. Mercury. Md. Code, Environment §6-906 prohibits the use or purchase of elemental or chemical mercury in primary or secondary classrooms. Any thermometers or other instruments containing mercury should be removed from student access immediately and properly disposed of by the school system. (Mercury thermometers can be identified by their silver- colored liquid.) When thermometers are needed, use alcohol-filled thermometers.

e. Smoke Generating Activities. Smoke of any kind affects the lungs because smoke is composed of particles floating in the air. Any classroom demonstration that produces smoke should be done in a fume hood, near an exhaust fan, or outdoors with students upwind.

f. Other Chemicals. Teachers should use only those chemicals that are on the local school system's list of approved chemicals or those approved by the school system science supervisor. In using an approved chemical, teachers may obtain technical information on the chemical from the Safety Data Sheet (SDS) provided by chemical supply companies. See Appendix C, Hazard Communications Standard.

4. Additional Safety Precautions

a. Students should wear chemical splash safety goggles and gloves when working with laboratory chemicals.

b. Students should be instructed not to taste any laboratory substances and to always wash their hands before and after use. Provide materials for washing hands after the science activity.

c. Instruct children not to mix substances at random to satisfy their curiosity.

d. Never pipette by mouth. Always use a pipette aspirator bulb.

e. Be alert to hazards presented by chemicals used in a science activity.

f. Keep flammable materials (e.g., cooking oil or paper) away from flames.

g. Instruct students to smell odors by wafting the odor toward them with a cupped hand.

See Chapter 7, Chemical Management, Handling and Disposal for more information.

H. OUTDOOR AND FIELD STUDIES SAFETY

Outdoor activities and field studies as a means of experiencing the environment can be a valuable addition to the science program. The greatest value is realized when educational objectives are clearly defined, and activities are designed to achieve those objectives in a safe manner. Safety is also achieved when teachers establish and enforce a set of rules, prepare the site prior to the study, and inform students and parents/guardians of the scope of the study and the environment in which it is to be conducted. Teachers help ensure safe outdoor activities also when they maintain up-to--date medical information and emergency phone numbers for all participants.

1. Safety Practices

Investigations and experiments outside the classroom are a valuable part of the science experience for the elementary student. The activity must be well-prepared and follow an approved plan.

Effective Safety Practices for Outdoor and Field Studies:

- Obtain required permissions from the school system, administration, and parents/guardians. Provide permissions in the student’s native language if possible.
- Visit the site prior to the trip and conduct a survey of the area. The survey should include identification of any conditions or potential dangers that need to be addressed in planning the trip.
- Determine the appropriateness of the outdoor activity or field study for all students based on any physical disabilities, allergies, or other conditions that could impair or limit their participation.
- Arrange for parents/guardians or other responsible adults to assist with supervision as required by school system policies.
- Make sure students know that regular school rules apply during outdoor activities and field study off campus.
- Establish any additional rules for safe student conduct and explain the rules to all participating students and adult supervisors.
- Be sure that first-aid kits are readily available and check the kits to make sure they contain the essential items.
- Prepare for emergencies with a method to contact the school office and up-to-date medical information and emergency telephone numbers for each student.
- Ensure the site is accessible for all students.

2. Plant Hazards

Plants can be used effectively to provide a living laboratory for elementary school science instruction. By providing experiential learning opportunities, teachers can help students to develop the kind of reasoned thinking that will result in responsible decision-making regarding human/ecosystem interaction. An example of this kind of knowledge is the fact that several poisonous plants, including poison ivy, are also important food for wildlife.

a. Poisonous Plants

- Teachers may want to confine their lessons on poisonous plants (poison ivy, poison oak or poison sumac) to pictures.
- Before using an outdoor learning area, examine the site for the presence of poisonous plants. When visiting these sites, carefully monitor the children to keep them away from the poisonous plants.
- Children should not put any plants in their mouths.

b. Effective Safety Practices for plant studies outdoors:

- Only plants that are not hazardous to children should be used.
- Caution children that they should never place any plant or part of a plant in the mouth.
- Avoid areas that have been sprayed with herbicides.
- Identify procedures for the immediate, on-site treatment for accidental ingestion of poisonous plant matter.
- Make hand washing routine procedure before and after any science activity, even when working with plants.

3. Animal Hazards

Animals can also be used to provide a living laboratory for elementary school science instruction. By providing experiential learning opportunities, teachers can help students to develop the kind of reasoned thinking that will result in responsible decision-making regarding human/ecosystem interaction. Particular care must be taken when interacting with animals in their natural setting.

Effective Safety Practices for animal studies outdoors:

- Avoid interacting with animals capable of injuring students, including poisonous or venomous animals, ticks, or mites during outdoor study.
- Be aware if any students are allergic to specific insect or animal bites.
- Identify procedures for the immediate, on-site treatment for insect or animal bites.

- Confirm that threatened or endangered animals are not present in the outdoor study area.
- Avoid areas that have been sprayed with pesticides.
- Do not remove any organisms from their natural habitat.
- Counting or classification of organisms should be done in a way to ensure that the organisms will have the greatest chance of survival when released back into the environment.
- Use plastic, paper, or cloth containers to prevent cuts and loss of specimens due to breakage. Avoid glass collection jars or containers.

See Chapter 8, Outdoor and Field Studies Safety for additional information.

I. ANIMALS IN THE ELEMENTARY CLASSROOM

The use of live animals in the classroom setting can help students understand and appreciate life processes. Before bringing animals into the classroom, teachers should check the school or school system policy. It is important to select animals that are appropriate to the instructional needs and are practical to maintain. Good safety procedures should be established for the protection of students from the hazards of classroom animals as well as to ensure humane treatment of animals.

Decisions to keep animals in the classroom should balance the ethical and responsible care of animals with their educational and social emotional value. The National Science Teaching Association's (NSTA) Position Statement on Responsible Use of Live Animals and Dissection in the Science Classroom and the National Association of Biology Teachers' (NABT) Principles and Guidelines for the Use of Animals in Precollege Education provide significant guidance.

NOTE: These precautions, hazards, and practices are intended for the classroom setting, and are not meant to restrict nature centers, or other partner organizations with animals for school programs.

1. Types of Hazards

Animals in the classroom can be hazardous in several ways.

a. Animals may contract and serve as carriers for human disease.

b. Animal scratches and bites can be hazardous to humans.

c. Animals can be sources of potentially severe allergies.

d. Animals may adversely affect classroom air quality.

2. Animals Not to be Kept in Elementary Schools

The following animals present an elevated risk of infection and/or injury to humans, they should not be kept in elementary schools:

a. Any venomous (poisonous) reptiles

b. Venomous fish

c. Black widow and brown recluse spiders

d. Scorpions

e. Bees, wasps, hornets, and other stinging insects

f. High-risk rabies carriers: bats, skunks, raccoons, foxes, minks, weasels, ferrets, opossums, unvaccinated dogs and cats, and other primates (including apes, monkeys, lemurs, marmosets)

g. All wild animals – dead or alive (except for those that have been properly prepared through taxidermy or similar professional procedures)

h. Any animals that can cause an allergic reaction to any student. Check with your school nurse/aide.

i. Any insect or arachnid (ticks, mites, spiders) capable of carrying disease into the classroom.

j. Household pets (with the expectation of service animals)

3. Animals Permitted with Caution

The following animals may be permitted, but check with your school system policies related to the noted caution(s):

a. Turtles and snakes: salmonella infection

b. Fur-bearing animals: cause of allergies and danger of bites

c. Tarantulas: biting

d. Parakeets and parrots: source of psittacosis infection

4. Effective Safety Practices for Permissible Animals in the Classroom

a. Obtain animals from a certified disease-free source (e.g., a qualified animal distributor or pet shop).

b. Use heavy gloves when handling animals.

c. Wash hands and exposed areas of the body with hot water and soap immediately after handling or feeding animals and after cleaning cages. Salmonella bacteria are common to a wide variety of reptiles.

d. Avoid hand-to-mouth contact when handling animals or cages.

e. Report any bite, scratch, or equipment-inflicted injury of a student to the school nurse or principal at once.

f. Rats, rabbits, hamsters, and mice are best picked up by the scruff of the neck, with the hand placed under the body for support.

g. All mammals used in the classroom should be inoculated for rabies.

h. Make sure guinea pigs, hamsters, and mice are certified by the vendor as "LCM free." LCM (lymphocytic choriomeningitis) is an uncommon but potentially serious viral disease transmitted to humans from these animals.

i. Clean and disinfect cages to ensure dry and odor-free care.

j. Obtain fish from tanks where all occupants appear healthy.

k. Make provisions for animal care over weekends and holidays.

l. The animal cage should be constructed of 1/4-inch wire mesh or smaller. A converted aquarium with a wire-mesh top may prove satisfactory.

m. Children should be cautioned never to tease animals or to insert fingers or objects through wire mesh cages.

n. When young are to be handled, first remove the mother to another cage.

o. Dispose of feces and bedding in a sanitary manner (flush down toilet or seal in plastic bag).

p. Do not incubate chicken eggs for hatching unless you have identified a permanent home for the chicks. Be prepared to keep the chicks for three weeks after hatching since Md. Code, Criminal Law, § 10-614 prohibits giving away or selling chicks less than three weeks old.

q. Do not release animals that are not indigenous to the area into the environment. The State Department of Natural Resources must approve release of indigenous animals.

See Chapter 9.D, Zoology: Animal Considerations for additional guidelines or more information.

J. CONTENT SPECIFIC SAFETY

Elementary science activities are related to multiple domains of science; life science, physical science, Earth/space science. There are potential hazards in all these science areas. Teachers should be prepared to complete a safety hazard assessment and address any safety issues that arise with any science lesson they teach. This section highlights some specific issues related to each domain.

1. Life Science Safety Practices

Some elementary science activities are related to life science (biology and environmental science). Things to consider are hazards associated with the handling of microorganisms, plants, and animals.

a. Effective Safety Practices for life science:

- Do not use direct sunlight for microscope illumination.
- Students with eye infections should not be allowed to contaminate the eyepiece(s) of the microscope.
- Teach students to pick up and transport a microscope with one hand under the base and one hand on the arm.
- When growing microorganisms on agar in petri dishes, proper decontamination/sterilization should be employed before discarding. Once sealed, agar plates should never be opened to examine. See Chapter 9.C, Microbiology, for proper procedures.
- Observe molds in closed containers. Many varieties produce spores that cause allergic reactions or are pathogenic to susceptible individuals.
- Only plants that are not hazardous to children should be used.
- For classroom study, only use plants with which you are familiar.
- Students should not put any plants or plant parts in their mouths. Some plants, like potato or rhubarb, have both edible parts and toxic parts.
- Treat commercial seeds with care because they may have been treated with toxic fungicides.
- Make hand washing routine procedure after any laboratory activity, even when working with plants.

b. Students as Subjects

Non-invasive, non-stress science activities involving students as experimental subjects are encouraged. These include physiological measurements such as pulse, heart rate, breathing rate, hearing, sight, etc. Obviously, every precaution must be taken to ensure student safety.

When respiratory experiments are done, remember that hyperventilation can be dangerous to anyone but particularly to asthmatics, epileptic people, and those who suffer from bronchial conditions.

c. Dissections

Teachers and school systems need to make informed decisions about the integration of dissection in the elementary science curriculum. All dissections should be conducted with consideration and appreciation of the organism, be appropriate for the maturity level of the students, and based on specific learning objectives and standards. Teachers should be open to providing suitable and equivalent alternative educational activities for students and parents/guardians who request non-dissection options.

- Purchase preserved specimens and tissues through reputable biological supply companies.
- Certain specimens, such as fish and squid, and some tissues, such as chicken wings, may be purchased from the local grocery store and should meet USDA standards for human consumption.
- Animals killed on highways and other non-preserved specimens cannot be used due to exposure to disease and bodily gases and fluids.
- Do not purchase or use any specimen that has been preserved in formaldehyde. Formaldehyde is a known human carcinogen.
- Specimens preserved in a safe, non-formaldehyde solution should be washed thoroughly before handling, and students should be instructed to use chemical splash safety goggles to prevent eye injury.
- Specimens and tissues should be bagged and then discarded appropriately.

See Chapter 9, Life Science for more information.

2. Earth/Space Science Safety Practices

Earth/space science offers many possibilities for rewarding elementary school science activities. The activities often involve concepts from chemistry and physics.

Effective Safety Practices for Earth/space science:

- Do not look directly at ultraviolet lamps as the light is dangerous to the eyes and skin.
- Do not look directly at the sun.
- Only observe a solar eclipse by indirect methods.
- Eyepieces of shared telescopes and binoculars should be cleaned between uses to reduce the risk of the transmission of eye infections.
- Do not flush sand, silt, clay, rocks, and other earth materials down the drain.

See Chapter 10, Earth/Space Science for more information.

3. Physical Science Safety Practices

Many of the hands-on activities in the elementary science classroom deal with the science of physical science. Topics discussed include hazards associated with mechanical equipment (falling weights, objects in motion), electricity (burns, shocks), chemicals, and rocketry.

a. Effective Safety Practices for physical science:

- Do not use a thermometer in boiling water unless it is designated for that use.
- Provide gloves for anyone handling glass wool or steel wool.
- Helium is an inert gas but, if inhaled, replaces oxygen, and can cause asphyxiation.
- Warning should be given to students when using masses in free fall or momentum activities to prevent hands and feet from being caught between a moving mass and floor or table surfaces.
- When using large magnets or electromagnets, students should be warned of the potential risk of pinching their hands between an object and the magnet.
- A stretched spring, unexpectedly released, can pinch fingers.
- A compressed spring, when suddenly released, can send an object at high velocity toward an observer.

b. Chemical Hazards:

- It is important to make the distinction between baking soda and washing soda. Baking soda is sodium hydrogen carbonate ($NaHCO_3$) and is harmless. Washing soda (or soda ash) is sodium carbonate (Na_2CO_3), a strongly alkaline substance and a strong irritant to the skin and eyes.
- Caustic soda is sodium hydroxide (lye-NaOH), an extremely powerful base. A strong irritant to eyes and skin, it is not recommended for classroom use.
- All chemicals, even those purchased from a grocery store, must have the SDS with it for reference. See Appendix C, Hazard Communications Standard.
- Do not use soda bottles, jam jars, condiment jars or retail plastic containers for storing chemicals.

c. Rocketry

Before beginning a model rocket program, check local school system regulations on the use of model rockets. Be sure also to check regulations about launch sites and fire codes in your area. See Chapter 11.H, Rocketry for more information.

- Only use lightweight materials such as paper, wood plastics and rubber, do not use metal as a structural part.

- Use only pre-loaded, factory-made model rocket engines in the manner recommended by the manufacturer. Do not alter or attempt to reload the engines.
- Do not launch a rocket in high winds or near buildings, power lines, tall trees, low flying aircraft, or under any conditions that might endanger people or property, such as the threat of lightning.
- All people should remain at least 10 feet from any rocket that is being launched.
- The launcher must have a jet deflector device to prevent the engine exhaust from hitting the ground directly.
- Do not let anyone approach a model rocket on a launcher until making sure that either the safety interlock key has been removed or the battery has been disconnected from the launcher.
- The system used to launch model rockets must be remotely controlled and electrically operated and must contain a switch that will return to "off" when released.
- Always use a rocket system with model rockets that will return them safely to the ground so that they may be flown again.
- Model rockets must weigh no more than 453 grams (16 oz.) at liftoff, and the engine must contain no more than 113 grams (4 oz.) of propellant.

See Chapter 11, Physical Science for more information.

4. Engineering Safety Considerations

Safety protocols must be in place for student safety when learning about science concepts and doing "fun and cool" science experiments with emphasis on engineering learning design outcomes.

a. Tools

Students must be at the proper developmental level and possess adequate motor skills for individual use of tools. Before allowing students to use power tools or common hand tools, teachers are expected to demonstrate the safe and practical application of that tool and the corresponding personal protective equipment needed. Do not assume that students know the names and functions of the tools you will be using.

- Teachers should never let students use any tool the teacher feels uncomfortable with or does not know how to use!
- Tools need to be used and stored appropriately in a secure location and sanitized prior and post usage.

- All tools must be in good working order before being used with students.
- Tools should be the proper size for the age and size of the students.
- Students should demonstrate an understanding of safe tool and equipment use to the teacher before working independently. Make sure they are using it safely.
- All tools should be used in the way they were intended. Misuse can result in damage to the tools and injury (using a screwdriver as a chisel).
- Wherever possible a jig or vise should be used to hold materials, allowing students to have both hands free.
- Cutting tools should be kept sharp and in good working order. The sharpness of a tool is essential for safety. Dull blades have the potential to reduce control and cause greater physical harm.
- Gloves may protect students' hands from accidental injury and should be a consideration for PPE when using saws, sharp instruments, and other cutting tools.
- The insulation of tool handles is necessary when working with electricity.
- Discard any hammer if it is dented, chipped, mushroomed, has a loose head, split handle or shows excessive wear.
- Impact tools, like hammers, may potentially cause discarded debris to fly, and every student within the work area should always wear safety glasses.
- Students and the teacher should wear proper protective safety equipment when working with thermal tools like hot glue guns, soldering irons, and heat guns.

b. 3D Printers

3D printers are engaging, provide innovative learning opportunities and promote CTE and workplace behaviors and skills needed in the workplace. However, 3D printing technology has become more affordable in recent years, can potentially pose a health risk because of its potential to release volatile organic chemicals (VOCs) and ultrafine particles (UFPs) into the air during operation. This could affect indoor air quality and may expose people to pollutants that may lead to adverse acute and chronic health concerns depending on the technology used in the classroom/laboratory and the HVAC on site.

Effective Safety strategies for using 3D printers:

- Ensure they are used in well-ventilated areas, have local exhaust fans, or are operated under a fume hood.

- Keep students from standing beside or hovering over a 3D printer while it is in operation.
- Set the printer nozzle temperature to the lower end of the suggested temperature range.
- Use 3D printers that can print PLA. Use PLA and not ABS in the printer whenever possible. PLA is made from cornstarch, is biodegradable and is considered safer.
- Use filaments that are specifically recommended by the manufacturer for the 3D printer.
- Use 3D printers and filaments that have been tested and verified to have low chemical and particle emissions.
- Use enclosed printers so students cannot get their fingers at the hot extruder. Never reach inside of a 3D printer while it is operating.
- Do not touch the printer head or reach into the 3D printer until it has cooled down.
- Some printers require a ‘perforated board’ to be used to stick the print to the board. These usually require a sharpened ‘scraper’ to remove. This is not a student friendly printer.

See Chapter 12, Engineering, Technology, and Application of Science for more information.

Appendix A: Safety Rules Agreement (SRA)

The study of science involves the use of a variety of equipment and materials to observe, identify, describe, and investigate phenomena in the physical world. The emphasis on hands-on activities -- including those that present potential hazards – makes safety in the science classroom the number one priority for students, instructors, and parents/guardians. A Safety Rules Agreement (SRA) can be a valuable tool to help ensure a safe science classroom. Below are two models of such agreements. Local school systems are encouraged to use these models in developing their own rules agreements tailored to the specific conditions and requirements of their science classes and laboratories. Provide agreements in the student's native language if possible.

A good SRA should include criteria for:

- student preparation for the laboratory,
- following instructions,
- basic precautions and procedures,
- proper handling of equipment and chemicals,
- use of personal protective equipment,
- responding to emergencies,
- laboratory housekeeping,
- notification of parents/guardians, and
- consequences for failure to follow safety procedures.

Once established, the rules must be followed at all times. It is recommended that, as a condition of participation in the classroom or laboratory, teachers require each student and parent/guardian to sign the agreement. Teachers should file a copy of each student's signed agreement, and students should keep a copy in their science notebooks as a reminder of the laboratory safety rules in the science classroom.

The following links provide sample SRA's:

1. NSTA Safety Acknowledgement Forms
   a. Elementary School
   b. Middle School
   c. High School
2. Flinn Scientific – Student Safety Contract

   a. Elementary School – English

   b. Middle School – English, Spanish

   c. High School – English, Spanish

3. Carolina – Student Laboratory Safety Agreement

4. Ward's Science – Laboratory Safety Contract

5. ACS - ChemClub Laboratory Safety Agreement

School systems should discuss the merits of using one SRA across the system or having different forms used by different schools within the system. Reaching out to the local school system's risk management office to develop a standardized SRA across the school system is also another internal conversation that should occur.

Appendix B: Chemical Hygiene Plan (CHP)

OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450), referred to as the Laboratory standard, specifies the mandatory requirements of a Chemical Hygiene Plan (CHP) to protect laboratory workers from harm due to hazardous chemicals. The CHP is a written program stating the policies, procedures, and responsibilities that protect workers from the health hazards associated with the hazardous chemicals used in that particular workplace.

A. REQUIRED CHP ELEMENTS

1. Standard operating procedures relevant to safety and health considerations for each activity involving the use of hazardous chemicals.

2. Criteria that the employer will use to determine and implement control measures to reduce exposure to hazardous materials [i.e., engineering controls, the use of personal protective equipment (PPE), and hygiene practices] with particular attention given to selecting control measures for extremely hazardous materials.

3. A requirement to ensure that fume hoods and other protective equipment are functioning properly and identify the specific measures the employer will take to ensure proper and adequate performance of such equipment.

4. Information to be provided to lab personnel working with hazardous substances include:

    - The contents of the Laboratory standard and its appendices.
    - The location and availability of the employer's CHP.
    - The permissible exposure limits (PELs) for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard.
    - The signs and symptoms associated with exposures to hazardous chemicals used in the laboratory.
    - The location and availability of known reference materials on the hazards, safe handling, storage, and disposal of hazardous chemicals found in the laboratory including, but not limited to, the Safety Data Sheets received from the chemical supplier.

5. The circumstances under which a particular laboratory operation, procedure or activity requires prior approval from the employer or the employer's designee before being implemented.

6. Designation of personnel responsible for implementing the CHP, including the assignment of a Chemical Hygiene Officer and, if appropriate, establishment of a Chemical Hygiene Committee.

7. Provisions for additional worker protection for work with particularly hazardous substances. These include “select carcinogens,” reproductive toxins and substances that have a high degree of acute toxicity. Specific consideration must be given to the following provisions and shall be included where appropriate:

    - Establishment of a designated area.
    - Use of containment devices such as fume hoods or glove boxes.
    - Procedures for safe removal of contaminated waste.
    - Decontamination procedures.

8. The employer must review and evaluate the effectiveness of the CHP at least annually and update it, as necessary.

B. WORKER TRAINING

Worker training must include:

- Methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.).
- The physical and health hazards of chemicals in the work area.
- The measures workers can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect workers from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used.
- The applicable details of the employer’s written CHP.

C. MEDICAL EXAMS AND CONSULTATION

The employer must provide all personnel who work with hazardous chemicals an opportunity to receive medical attention, including any follow-up examinations which the examining physician determines to be necessary, under the following circumstances:

- Whenever a worker develops signs or symptoms associated with a hazardous chemical to which the worker may have been exposed in the laboratory, the worker must be provided an opportunity to receive an appropriate medical examination.
- Where exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the PEL) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance must be established for the affected worker(s) as prescribed by the particular standard.
- Whenever an event takes place in the work area such as a spill, leak, explosion, or other occurrence resulting in the likelihood of a hazardous exposure, the affected worker(s) must be

provided an opportunity for a medical consultation to determine the need for a medical examination.

- All medical examinations and consultations must be performed by or under the direct supervision of a licensed physician and be provided without cost to the worker, without loss of pay, and at a reasonable time and place.

D. SUGGESTED ELEMENTS OF A CHEMICAL HYGIENE PLAN

1. Hazard identification including proper labeling of containers of hazardous chemicals and maintaining SDSs in a readily accessible location.

2. Requirements to establish and maintain accurate records monitoring employee exposures and any medical consultation and/or examinations, and to assure the confidentiality of these records.

3. Appendix A of 29 CFR 1910.1450 provides non-mandatory recommendations to help in developing a CHP.

E. ADDITIONAL INFORMATION

1. Although only employees are covered under OSHA standards, students should also follow the Laboratory standard components, given they help to secure a safer working environment not only for themselves but also for employees (teachers, etc.).

2. For additional information on developing a CHP consult the following sources:

   a. Laboratory safety standard at the OSHA Web site.

   b. *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals* by The National Research Council (2011).

   c. NSTA: Chemical Hygiene Plan: Quick-Reference Guide

   d. Flinn Scientific: Sample CHP.

Appendix C: Hazard Communications Standard

In 2012, the Occupational Safety and Health Administration (OSHA) announced the adoption of the United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS). The adoption of GHS was a revision to the Hazard Communication Standard (29 CFR 1910.1200) and by extension the Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450) or Laboratory Standard. These standards outline the rights of teachers and other employees to understand the hazards of the chemicals that they work with.

A. HAZARDOUS COMMUNICATIONS STANDARD

The purpose of the Hazardous Communications Standard is to ensure that the hazards of all chemicals produced or imported are classified, and that information concerning the classified hazards is transmitted to employers and employees. This standard requires chemical manufacturers or importers to provide the following:

- **Hazard classification**: Provides specific criteria for classification of health and physical hazards, as well as classification of mixtures.
- **Labels**: Chemical manufacturers and importers are required to provide a label that includes a harmonized signal word, hazard pictogram, manufacturer information, precautionary statements/first aid, hazard statement and product name or identifiers for each hazard class and category. Precautionary statements must also be provided.
- **Safety Data Sheets**: Have a GHS specified 16-section format.
- **Information and training**: Employers are required to train workers on the label elements and Safety Data Sheets format to facilitate recognition and understanding.

B. SAFETY DATA SHEETS (SDS)

The SDS includes information such as the properties of each chemical; the physical, health, and environmental health hazards; protective measures; and safety precautions for handling, storing, and transporting the chemical. The information contained in the SDS must be in English (although it may be in other languages as well). In addition, OSHA requires that SDS preparers provide specific minimum information as detailed in Appendix D of 29 CFR 1910.1200. The SDS preparers may also include additional information in various section(s).

Sections 1 through 8 contain general information about the chemical, identification, hazards, composition, safe handling practices, and emergency control measures (e.g., firefighting). This information should be helpful to those who need to get the information quickly. Sections 9 through 11 and 16 contain other technical and scientific information, such as physical and chemical properties, stability and reactivity information, toxicological information, exposure control information, and other information including the date of preparation or last revision. The SDS must also state that no applicable information was found when the preparer did not find relevant information for any required element. The SDS must also contain Sections 12 through 15, to be consistent with the UN Globally

Harmonized System of Classification and Labeling of Chemicals (GHS), but OSHA will not enforce the content of these sections because they concern matters handled by other agencies. A description of all 16 sections of the SDS, along with their contents, is presented below:

1. **Identification**

   This section identifies the chemical on the SDS as well as the recommended uses. It also provides the essential contact information of the supplier. The required information consists of:

   - Product identifier used on the label and any other common names or synonyms by which the substance is known.
   - Name, address, phone number of the manufacturer, importer, or other responsible party, and emergency phone number.
   - Recommended use of the chemical (e.g., a brief description of what it actually does, such as flame retardant) and any restrictions on use (including recommendations given by the supplier).

2. **Hazard(s) Identification**

   This section identifies the hazards of the chemical presented on the SDS and the appropriate warning information associated with those hazards. The required information consists of:

   - The hazard classification of the chemical (e.g., flammable liquid, category1).
   - Signal word.
   - Hazard statement(s).
   - Pictograms (the pictograms or hazard symbols may be presented as graphical reproductions of the symbols in black and white or be a description of the name of the symbol (e.g., skull and crossbones, flame).
   - Precautionary statement(s).
   - Description of any hazards not otherwise classified.
   - For a mixture that contains an ingredient(s) with unknown toxicity, a statement describing how much (percentage) of the mixture consists of ingredient(s) with unknown acute toxicity. Please note that this is a total percentage of the mixture and not tied to the individual ingredient(s).

3. **Composition/Information on Ingredients**

   This section identifies the ingredient(s) contained in the product indicated on the SDS, including impurities and stabilizing additives. This section includes information on substances, mixtures, and all chemicals where a trade secret is claimed. The required information consists of:

a. Substances

- Chemical name.
- Common names and synonyms.
- Chemical Abstracts Service (CAS) number and other unique identifiers.
- Impurities and stabilizing additives, which are themselves classified and which contribute to the classification of the chemical.

b. Mixtures

- Same information required for substances.
- The chemical name and concentration (i.e., exact percentage) of all ingredients which are classified as health hazards and are:
  - o Present above their cut-off/concentration limits or
  - o Present a health risk below the cut-off/concentration limits.
- The concentration (exact percentages) of each ingredient must be specified except concentration ranges may be used in the following situations:
  - o A trade secret claim is made,
  - o There is batch-to-batch variation, or
  - o The SDS is used for a group of substantially similar mixtures.

c. Chemicals where a trade secret is claimed

- A statement that the specific chemical identity and/or exact percentage (concentration) of composition has been withheld as a trade secret is required.

4. First-Aid Measures

This section describes the initial care that should be given by untrained responders to an individual who has been exposed to the chemical. The required information consists of:

- Necessary first-aid instructions by relevant routes of exposure (inhalation, skin and eye contact, and ingestion).
- Description of the most important symptoms or effects, and any symptoms that are acute or delayed.
- Recommendations for immediate medical care and special treatment needed, when necessary.

5. Fire-Fighting Measures

This section provides recommendations for fighting a fire caused by the chemical. The required information consists of:

- Recommendations of suitable extinguishing equipment, and information about extinguishing equipment that is not appropriate for a particular situation.
- Advice on specific hazards that develop from the chemical during the fire, such as any hazardous combustion products created when the chemical burns.
- Recommendations on special protective equipment or precautions for firefighters.

6. Accidental Release Measures

This section provides recommendations on the appropriate response to spills, leaks, or releases, including containment and cleanup practices to prevent or minimize exposure to people, properties, or the environment. It may also include recommendations distinguishing between responses for large and small spills where the spill volume has a significant impact on the hazard. The required information may consist of recommendations for:

- Use of personal precautions (such as removal of ignition sources or providing sufficient ventilation) and protective equipment to prevent the contamination of skin, eyes, and clothing.
- Emergency procedures, including instructions for evacuations, consulting experts when needed, and appropriate protective clothing.
- Methods and materials used for containment (e.g., covering the drains and capping procedures).
- Cleanup procedures (e.g., appropriate techniques for neutralization, decontamination, cleaning, or vacuuming; adsorbent materials; and/or equipment required for containment/clean up).

7. Handling and Storage

This section provides guidance on the safe handling practices and conditions for safe storage of chemicals. The required information consists of:

- Precautions for safe handling, including recommendations for handling incompatible chemicals, minimizing the release of the chemical into the environment, and providing advice on general hygiene practices (e.g., eating, drinking, and smoking in work areas is prohibited).
- Recommendations on the conditions for safe storage, including any incompatibilities. Provide advice on specific storage requirements (e.g., ventilation requirements).

8. Exposure Controls/Personal Protection

This section indicates the exposure limits, engineering controls, and personal protective measures that can be used to minimize worker exposure. The required information consists of:

- OSHA Permissible Exposure Limits (PELs), American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the safety data sheet, where available.
- Appropriate engineering controls (e.g., use local exhaust ventilation, or use only in an enclosed system).
- Recommendations for personal protective measures to prevent illness or injury from exposure to chemicals, such as personal protective equipment (PPE) (e.g., appropriate types of eye, face, skin or respiratory protection needed based on hazards and potential exposure).
- Any specific requirements for PPE, protective clothing, or respirators (e.g., type of glove material, such as PVC or nitrile rubber gloves; and breakthrough time of the glove material).

2. **Physical and Chemical Properties**

This section identifies physical and chemical properties associated with the substance or mixture. The minimum required information consists of:

- Appearance (physical state, color, etc.);
- Upper/lower flammability or explosive limits;
- Odor;
- Vapor pressure;
- Odor threshold;
- Vapor density;
- pH;
- Relative density;
- Melting point/freezing point;
- Solubility(ies);
- Initial boiling point and boiling range;
- Partition coefficient: n-octanol/water;
- Flash point;
- Auto-ignition temperature;

- Evaporation rate;
- Decomposition temperature;
- Flammability (solid, gas); and
- Viscosity.

The SDS may not contain every item on the above list because information may not be relevant or is not available. When this occurs, a notation to that effect must be made for that chemical property. Manufacturers may also add other relevant properties, such as the dust deflagration index (Kst) for combustible dust, used to evaluate a dust's explosive potential.

3. Stability and Reactivity

This section describes the reactivity hazards of the chemical and the chemical stability information. This section is broken into three parts: reactivity, chemical stability, and other. The required information consists of:

a. Reactivity

- Description of the specific test data for the chemical(s). This data can be for a class or family of the chemical if such data adequately represent the anticipated hazard of the chemical(s), where available.

b. Chemical stability

- Indication of whether the chemical is stable or unstable under normal ambient temperature and conditions while in storage and being handled.
- Description of any stabilizers that may be needed to maintain chemical stability.
- Indication of any safety issues that may arise should the product change in physical appearance.

c. Other

- Indication of the possibility of hazardous reactions, including a statement whether the chemical will react or polymerize, which could release excess pressure or heat, or create other hazardous conditions. Also, a description of the conditions under which hazardous reactions may occur.
- List of all conditions that should be avoided (e.g., static discharge, shock, vibrations, or environmental conditions that may lead to hazardous conditions).
- List of all classes of incompatible materials (e.g., classes of chemicals or specific substances) with which the chemical could react to produce a hazardous situation.

- List of any known or anticipated hazardous decomposition products that could be produced because of use, storage, or heating. (Hazardous combustion products should also be included in Section 5 (Fire-Fighting Measures) of the SDS.)

4. Toxicological Information

This section identifies toxicological and health effects information or indicates that such data are not available. The required information consists of:

- Information on the routes of exposure (inhalation, ingestion, skin and eye contact). The SDS should indicate if the information is unknown.
- Description of the delayed, immediate, or chronic effects from short- and long-term exposure.
- The numerical measures of toxicity (e.g., acute toxicity estimates such as the LD50 (median lethal dose)) - the estimated amount [of a substance] expected to kill 50% of test animals in a single dose.
- Description of the symptoms. This description includes the symptoms associated with exposure to the chemical including symptoms from the lowest to the most severe exposure.
- Indication of whether the chemical is listed in the National Toxicology Program (NTP) Report on Carcinogens (latest edition) or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs (latest editions) or found to be a potential carcinogen by OSHA.

5. Ecological Information

This section provides information to evaluate the environmental impact of the chemical(s) if it were released to the environment. The information may include:

- Data from toxicity tests performed on aquatic and/or terrestrial organisms, where available (e.g., acute or chronic aquatic toxicity data for fish, algae, crustaceans, and other plants; toxicity data on birds, bees, plants).
- Whether there is a potential for the chemical to persist and degrade in the environment either through biodegradation or other processes, such as oxidation or hydrolysis.
- Results of tests of bioaccumulation potential, referring to the octanol-water partition coefficient (Kow) and the bioconcentration factor (BCF), where available.
- The potential for a substance to move from the soil to the groundwater (indicate results from adsorption studies or leaching studies).

- Other adverse effects (e.g., environmental fate, ozone layer depletion potential, photochemical ozone creation potential, endocrine disrupting potential, and/or global warming potential).

6. **Disposal Considerations**

This section provides guidance on proper disposal practices, recycling or reclamation of the chemical(s) or its container, and safe handling practices. To minimize exposure, this section should also refer the reader to Section 8 (Exposure Controls/Personal Protection) of the SDS. The information may include:

- Description of appropriate disposal containers to use.
- Recommendations of appropriate disposal methods to employ.
- Description of the physical and chemical properties that may affect disposal activities.
- Language discouraging sewage disposal.
- Any special precautions for landfills or incineration activities.

7. **Transport Information**

This section provides guidance on classification information for shipping and transporting of hazardous chemical(s) by road, air, rail, or sea. The information may include:

- UN number (i.e., four-figure identification number of the substance).
- UN proper shipping name.
- Transport hazard class(es).
- Packing group number, if applicable, based on the degree of hazard.
- Environmental hazards (e.g., identify if it is a marine pollutant according to the International Maritime Dangerous Goods Code (IMDG Code)).
- Guidance on transport in bulk (according to Annex II of MARPOL 73/78 and the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (International Bulk Chemical Code (IBC Code)).
- Any special precautions which an employee should be aware of or needs to comply with, in connection with transport or conveyance either within or outside their premises (indicate when information is not available).

8. **Regulatory Information**

This section identifies the safety, health, and environmental regulations specific for the product that is not indicated anywhere else on the SDS. The information may include:

- Any national and/or regional regulatory information of the chemical or mixtures (including any OSHA, Department of Transportation, Environmental Protection Agency, or Consumer Product Safety Commission regulations).

9. **Other Information**

   This section indicates when the SDS was prepared or when the last known revision was made. The SDS may also state where the changes have been made to the previous version. You may wish to contact the supplier for an explanation of the changes. Other useful information may also be included here.

C. LABEL ELEMENTS

The Hazard Communications Standards requires the following information to appear on every chemical label:

1. The supplier identifier includes the name, address and telephone number of the chemical manufacturer, importer, or other responsible party.

2. The product identifier is how the hazardous chemical is identified. This can include the chemical name, code number, or batch number. This same information must be on both the label and the safety data sheet.

3. Symbols (GHS hazard pictograms) convey health, physical, and environmental hazard information assigned to a GHS hazard class and category. Pictograms include the harmonized hazard symbols plus other graphic elements, such as borders, background patterns, and substances that have target organ toxicity.

4. Signal Words–these are words that are used to describe the severity of the hazard. Only two words are used as signal words, “Danger” and “Warning”. “Danger” is used for more severe hazards.

5. Hazard Statements–these statements include the nature of the hazard(s) of a chemical and the degree of the hazard.

6. Precautionary Statements–these statements describe measures that are recommended to minimize or prevent adverse effects resulting from exposure to the hazardous chemical or improper storage and handling. There are four types of precautionary statements: prevention, response, storage, and disposal.

7. Supplementary Information–the manufacturer may provide additional information that it deems helpful.

8. Employer Responsibilities–employers are responsible for maintaining labels on containers.

9. Workplace Labels–employers continue to have the option to create their own chemical labels, these labels must have all of the information that is on the manufacturer’s label.

GHS Label Sample:

Pictograms – these are symbols used to communicate information about the hazards of a product.

Health Hazard

- Carcinogen
- Mutagenicity
- Reproductive Toxicity
- Respiratory Sensitizer
- Target Organ Toxicity
- Aspiration Toxicity

Flame

- Flammables
- Pyrophorics
- Self-Heating
- Emits Flammable Gas
- Self-Reactives
- Organic Peroxides

Exclamation Mark

- Irritant (skin and eye)
- Skin Sensitizer
- Acute Toxicity (harmful)
- Narcotic Effects
- Respiratory Tract Irritant
- Hazardous to Ozone Layer (Non Mandatory)

Gas Cylinder

- Gases under Pressure

Corrosion

- Skin Corrosion/ burns
- Eye Damage
- Corrosive to Metals

Exploding Bomb

- Explosives
- Self-Reactives
- Organic Peroxides

Flame over Circle

- Oxidizers

Environment (Non Mandatory)

- Aquatic Toxicity

Skull and Crossbones

- Acute Toxicity (fatal or toxic)

D. ADDITIONAL RESOURCES

1. OSHA Brief, Hazard Communication Standard: Labels and Pictograms
2. OSHA Brief, Hazard Communication Standard: Safety Data Sheets
3. OSHA Quick Card, Hazard Communication Standard Pictogram
4. OSHA Website, Hazard Communication Pictograms Files
5. NSTA Paper: Globally Harmonized System of Classification and Labeling of Chemicals
6. United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS)

Appendix D: Safety Checklists

SCIENCE CLASSROOM SAFETY INSPECTION CHECKLIST

Room: ________________ Inspector: ____________________________ Date: _________________

Proper operation of:	Satisfactory	Unsatisfactory	Date Remedied
Eyewash fountain			
Safety Shower			
Fume Hood			
Ventilation			

Condition of:	Satisfactory	Unsatisfactory	Date Remedied
Fire Extinguishers			
Fire Blanket			
First-aid kit			
Spill clean-up kits			
Safety goggles			
Lab aprons			

Hazards	Satisfactory	Unsatisfactory	Date Remedied
Exits are not blocked			
Aisles are not cluttered			
Chemicals are not stored in the room			
Glassware is not cracked or broken			
Proper waste receptacles for broken glass and other sharp objects			
Chemicals are properly labeled			

Housekeeping	Satisfactory	Unsatisfactory	Date Remedied
Sinks and sink traps are clean, unblocked			
Fume hood is clean, clear of clutter			
Work counter tops are clean, clutter-free			
Tabletops are clean			
No food or drink is in lab areas			
Broken glass container is available			
Waste containers for chemicals are available			

SAFETY CHECKLIST FOR CHEMICAL STOREROOMS

Room: ________________ Inspector: ____________________________ Date: _________________

Area of Concern	Yes	No	Date Remedied
The storeroom is properly labeled.			
The storeroom can be locked and access restricted.			
Fire resistant cabinets for flammable liquids are available.			
All chemical refrigerators are explosion proof and labeled NO FOOD.			
The shelving is secured to the wall or floor.			
The chemical shelving has raised edges to prevent accidents.			
Ventilation is adequate.			
Chemicals are stored according to their chemical properties.			
Acids (greater than 6M) are stored in corrosion-resistant cabinets.			
Leakproof containers are available for transporting corrosive chemicals.			
An annually updated inventory of chemicals is available.			
SDS sheets are available for every chemical.			
State Safety Manual and Chemical Hygiene plan are available.			
Peroxide-forming chemicals are marked with the date opened and tested for peroxides every 6 months or disposed of.			
Gas cylinders are firmly secured.			
Waste-chemical and waste-solvent containers are capped and clearly labeled.			
All containers of chemicals are clearly labeled with the name of the chemical, appropriate hazard warning, and name of manufacturer.			
Reagent and solution labels contain the date mixed, name of chemical, and name of preparer.			
All containers are free of rust and corrosion.			
Explosion-proof lightening.			
Grounding and bonding wires are available for spark-free transfer of flammable liquids.			
Containers are dated when received and opened.			
New containers are marked to show the full level.			
Glass containers are stored in a manner to prevent breakage.			

ELECTRICAL SAFETY INSPECTION CHECKLIST

Room: ________________ Inspector: ____________________________ Date: _________________

Situation	Yes	No	Date Remedied
All circuit breakers in the panel(s) are clearly labeled.			
The circuit breaker panel(s) are not obstructed.			
An emergency power shut off is present			
Ground fault interrupters are used for receptacles where water may be present.			
Receptacles are tested annually with a ground monitor.			
All appliances in the lab have three wire grounded cords.			
The cases of appliances are tested annually for voltage leaks with an AC-Sensor or other field detecting device.			
Extension cords are not used for permanent installations.			
Receptacles are tested annually with a tension tester (Woodhead Receptacle Tension Tester) to determine whether they have a sufficiently strong grip to meet code.			
Extension cords are not a tripping hazard.			
Electric cords are not worn or frayed.			
The circular fiber guard covering the wiring connections is present on older plugs.			
Two-prong unpolarized plugs are inserted so that the ripple side of the cord is connected to the wider (neutral) side of the receptacle.			
An emergency plan exists for dealing with electric shock incidents.			

Appendix E: National Fire Protection Association (NFPA) Identification Codes

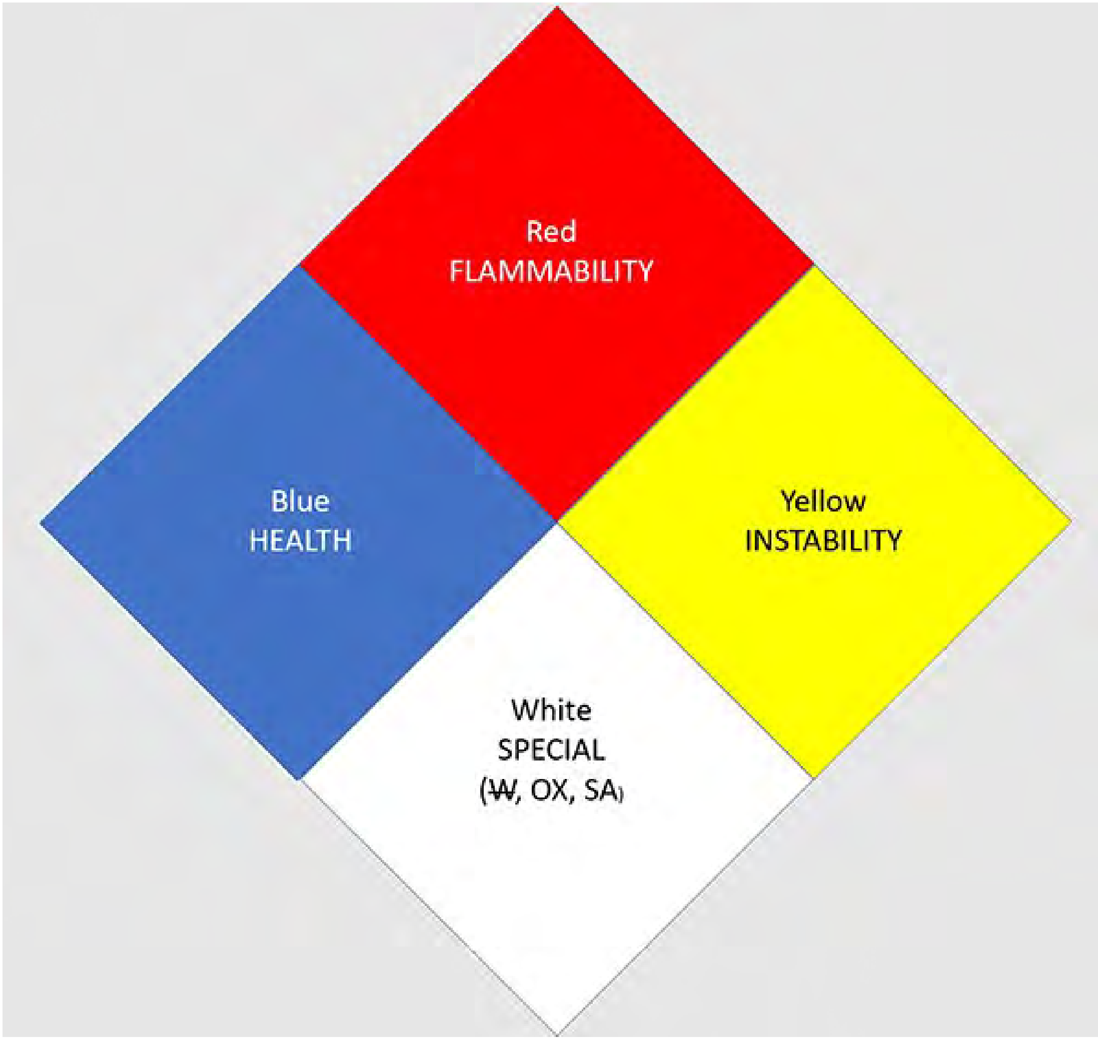
Hazardous materials are defined in NFPA codes and standards as chemicals or substances that are classified as a physical hazard or a health hazard. Physical hazard materials are those classified as an explosive, flammable cryogen, flammable gas, flammable solid, ignitable liquid, organic peroxide, oxidizer, oxidizing cryogen, pyrophoric, unstable (reactive), or water-reactive material. Health hazard materials are those classified as toxic, highly toxic, or corrosive material. NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, specifies the identification requirements for these materials. NFPA 704 applies when another Federal, state, or local regulation or code requires its use.

The purpose of the standard is to provide a simple, readily recognized, and easily understood system of markings that provides a general idea of the hazards of a material and the severity of the hazards as they relate to emergency response. The identification system specified in NFPA 704 is intended to enable first responders to easily decide whether to evacuate the area or to commence emergency control procedures and to also provide information to assist in selecting firefighting tactics and emergency procedures.

HAZARD IDENTIFICATION SYSTEM

The NFPA 704 hazard identification system is characterized by a diamond which is more precisely defined as a “square-on-point” shape. It identifies the degree of severity of the health, flammability, and instability hazards. Hazard severity is indicated by a numerical rating that ranges from zero (0) indicating a minimal hazard, to four (4) indicating a severe hazard. The hazards are arranged spatially such that health hazards are indicated in the nine o’clock position, flammability at the twelve o’clock position, and instability at the three o’clock position. The six o’clock position on the symbol represents special hazards and has a white background; it is not always filled. When it is these symbols are used:

- ~~W~~ = Water reactivity (avoid the use of water)
- OX = Oxidizer
- SA = Simple asphyxiant (nitrogen, helium, neon, krypton, or xenon)



HEALTH RATINGS

4 - Materials that, under emergency conditions, can be lethal.

3 - Materials that, under emergency conditions, can cause serious or permanent injury.

2 - Materials that, under emergency conditions, can cause temporary incapacitation or residual injury.

1 - Materials that, under emergency conditions, can cause significant irritation.

0 - Materials that, under emergency conditions, would offer no hazard beyond that of ordinary combustible materials.

FLAMMABILITY RATINGS

4 - Materials that will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or that are readily dispersed in air, and which will burn readily.

3 - Liquids and solids that can be ignited under almost all ambient temperature conditions. Materials in this degree produce hazardous atmospheres with air under almost all ambient temperatures or, though unaffected by ambient temperatures, are readily ignited under almost all conditions.

2 - Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur. Materials to this degree would not under normal conditions form hazardous atmospheres with air, but under high ambient temperatures or under moderate heating might release vapor in sufficient quantities to produce hazardous atmospheres with air.

1 - Materials that must be preheated before ignition can occur. Materials to this degree require considerable preheating, under all ambient temperature conditions, before ignition and combustion can occur.

0 - Materials that will not burn. This includes any material that will not burn in air when exposed to a temperature of 1500EF (815.5EC) for a period of 5 minutes.

INSTABILITY RATINGS

4 - Materials that in themselves are readily capable of detonation or explosive decomposition or explosive reaction at normal temperatures and pressures. This includes materials which are sensitive to localized thermal or mechanical shock at normal temperatures and pressures.

3 - Materials that in themselves are capable of detonation or explosive decomposition or explosive reaction but that require a strong initiating source or that must be heated under confinement before initiation.

2 - Materials that readily undergo violent chemical change at elevated temperatures and pressures.

1 - Materials that in themselves are normally stable but that can become unstable at elevated temperatures and pressures.

0 - Materials that in themselves are normally stable, even under fire conditions.

Appendix F: Storage of Chemicals

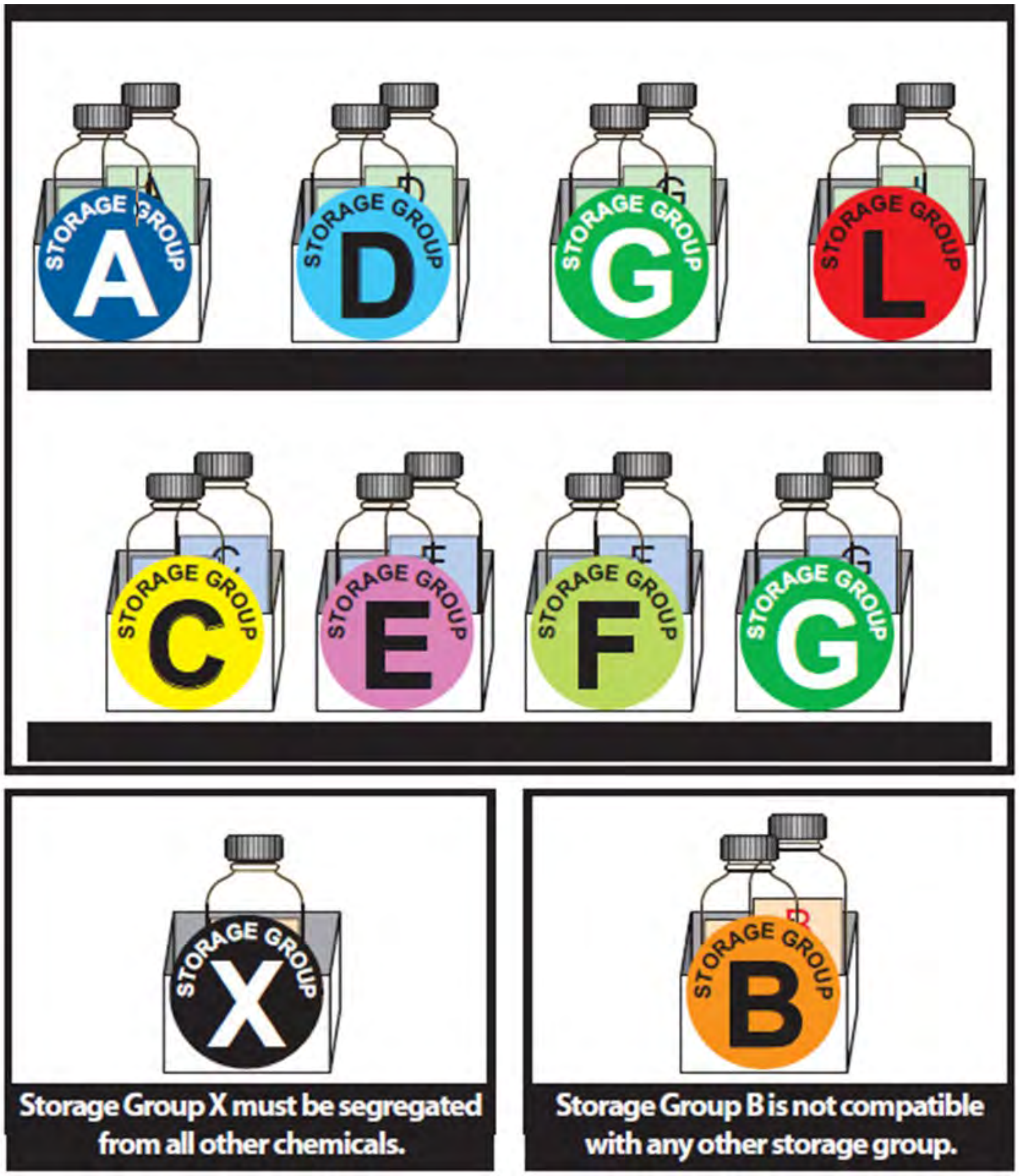
It is important to avoid storing incompatible chemicals together. Separation of incompatibles will reduce the risk of mixing in case of accidental breakage, fire, earthquake, or response to a laboratory emergency. Even when containers are tightly closed, fugitive vapors can cause deleterious incompatibility reactions that degrade labels, shelves, cabinets, and containers themselves.

The table, from *Prudent Practices in the Laboratory* (2011), shows an example of a classification system for the storage of groups of chemicals by compatibility. The system classifies chemicals into 11 storage groups. Each group should be separated by secondary containment (e.g., plastic trays) or, ideally, stored in its own storage cabinet. It is most important to separate storage groups B and X in their own storage cabinets.

Code	Storage Group	Chemicals
A	Compatible Organic Bases	Diethylamine, Piperidine, Triethanolamine, Benzylamine, Benzyltrimethylammonium hydroxide
B	Compatible Pyrophoric & Water-Reactive Materials	Sodium borohydride, Benzoyl chloride, Zinc dust, Alkyl lithium solutions such as methyl lithium in tetrahydrofuran, Methanesulfonyl chloride, Lithium aluminum hydride
C	Compatible Inorganic Bases	Sodium hydroxide, Ammonium hydroxide, Lithium hydroxide, Cesium hydroxide
D	Compatible Organic Acids	Acetic acid, Citric acid, Maleic acid, Propionic acid, Benzoic acid
E	Compatible Oxidizers Including Peroxides	Nitric acid, Perchloric acid, Sodium hypochlorite, Hydrogen peroxide, 3-Chloroperoxybenzoic acid
F	Compatible Inorganic Acids Not Including Oxidizers or Combustibles	Hydrochloric acid, Sulfuric acid, Phosphoric acid, Hydrogen fluoride solution
G	Not Intrinsically Reactive or Flammable or Combustible	Acrylamide, Sodium Bisulfate, Coomassie Blue, Sodium Chloride
J*	Poison Compressed Gases	Sulfur dioxide, Hexafluoropropylene
K*	Compatible Explosives or Other Highly Unstable Materials	Picric acid dry (<10% H_2O), Nitroguanidine, Tetrazole, Urea nitrate
L	Nonreactive Flammables and Combustibles, Including Solvents	Benzene, Methanol, Toluene, Tetrahydrofuran
X*	Incompatible with ALL Other Storage Groups	Picric acid moist (10-40% H_2O), Phosphorus, Benzyl azide, Sodium hydrogen sulfide

*Chemicals in Group J, K and X are mentioned here for thoroughness, but these are chemicals that should not be present in a school building.

If space does not allow Storage Groups to be kept in separate cabinets the following scheme, from Stanford University's ChemTracker Storage System can be used with extra care taken to provide stable, uncrowded, and carefully monitored conditions. Also be sure to follow any storage information on the container's label or on the chemical's SDS.



There are other good classification systems for storing chemicals according to compatibility. At a minimum, always store fuels away from oxidizers. In other systems, the following chemical groups are kept separate by using secondary containment, cabinets, or distance:

- oxidizers, including peroxides;
- corrosives—inorganic bases;
- corrosives—inorganic acids, not including oxidizers or combustibles;

- flammable materials;
- reproductive toxins;
- select carcinogens; and
- substances with a high degree of acute toxicity.

Appendix G: Hazards of Peroxide-Forming Substances

Organic peroxides are dangerous materials. They are potentially explosive through a polymerization reaction triggered by a free-radical mechanism. Many organic peroxides are auto oxidants; that is, they react with the oxygen in the air to form peroxides. Once formed, these peroxides are extremely sensitive to heat, and especially, shock. Simply unscrewing the cap or removing the stopper from a container of peroxide material may be sufficient to detonate it. If any of the substances listed below are used in the laboratory, any remaining material should be destroyed promptly. The shelf life of most of these substances will be listed in the SDS. If you cannot find a good reference for the shelf life, assume it is 3 months.

Below is a list of substances that, under certain circumstances, can form dangerous peroxides.

Acetal

Acetic acid

Acrylonitrile

Butadiene

Chlorobutadiene

Chlorotrifluoroethylene

Cumene

Cyclohexene

Cyclooctene

Cyclopentene

Diacetylene

Dicyclopentadiene

Diethylene glycol dimethyl ether

Diethyl ether

Dioxane

Divinyl ether

Divinylacetylene

Ethylene glycol dimethyl ether

Furan

Isopropyl ether

Methylacetylene

Methylcyclopentane

Methyl iso-butyl ketone

Methyl methacrylate

Potassium

Potassium amide

Sodium amide

Styrene

Tetrafluoroethylene

Tetrahydrofuran

Tetrahydronaphthalene

Vinyl acetate

Vinyl acetylene

Vinyl chloride

Vinyl ethers

Vinyl pyridine

Vinylidene chloride