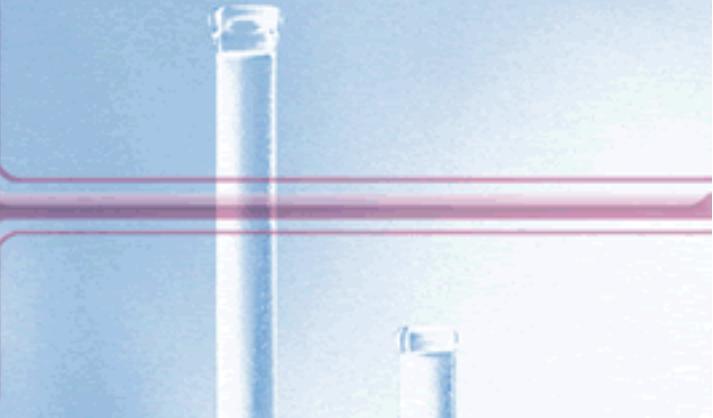


MARYLAND

SCIENCE SAFETY MANUAL K-12



Maryland Science
Supervisors Association



With support from the
Maryland State
Department of Education



ACKNOWLEDGMENTS

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Preface

The Maryland Science Safety Manual K-12 was a joint project of the Maryland Science Supervisors Association (MSSA) and the Maryland State Department of Education (MSDE). Funding for the project was provided through a grant from MSDE, and both organizations provided leadership. This project was an extension of an earlier three-year science safety project that issued a safety manual in 1985. That manual provided the basic direction and philosophy for the current document.

Development of the current 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. Writing began in the summer of 1998, and a draft document was completed in the fall of 1998 and distributed to organizations for review. Many of the suggestions from the reviewing groups have been incorporated into the Manual.

The Science Safety Manual was written to be a comprehensive set of safety guidelines for use by local school systems and schools in providing safe classroom instruction in science. The Manual is designed to be used in its entirety. As much as possible, redundancies within and between chapters I through XI were eliminated. Chapter XII summarizes the earlier chapters for the elementary school teacher while eliminating areas that typically do not apply to the elementary school classroom.

Special effort was made to provide teachers and administrators with additional sources of both print and electronic resources. These resources are listed in Appendix H and indicated in margin notes throughout the document.

The document has been distributed to science supervisors in the 24 local school systems. The Manual also is available on the MSDE website, where it is readily accessible to teachers, administrators, and others interested in safety in the science classroom and laboratory. Online publication allows for regular revisions to ensure that the Manual presents the most current information in the most useful format possible.

We invite all users of this Manual to pass along ideas for its improvement to the Maryland Science Supervisors Association or the Science Specialist in the Maryland State Department of Education. Such sharing of ideas will go far 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.

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Maryland schools and school systems are encouraged to reprint this publication for their use. Other educators may reprint the document with proper credit to the Maryland Science Safety Project of the Maryland Science Supervisors Association and Maryland State Department of Education.

Introduction

Providing a Stimulating and Safe Environment for Science Studies

By its very nature, experimental science encourages teachers and students to create new techniques and apparatus to investigate both old and new ideas. In the stimulating science classroom, it is impossible to anticipate all of the specific hazards that might arise. It is not necessary to eliminate creativity in the interest of safety. It is important, however, that teachers temper their creativity with a constant alertness to potential dangers. Common sense can go a long way toward maintaining a safe environment.

The ultimate responsibility for safety in the science classroom lies with the school administration in general and the school principal in particular.

Administrators should be familiar with the general provisions of this Manual and insist on the implementation of its requirements. Teachers and students, however, bear the day-to-day responsibility for safety. For this reason, the details of the safety program enumerated in this Manual are directed primarily to the teacher. Yet, a safety program can only be effective if all parties carry out their responsibilities. It is essential that the safety program have the full support of all school and central office administrators as well as parents.

"The aim is to make safety a part of students' basic approach to the laboratory

To teach science effectively, the teacher must teach it safely. The first step is to establish an effective, continuous safety program. Many of the materials and procedures used in teaching science are *potentially* dangerous. It is the purpose of a safety program to prevent that potentiality from becoming reality. This means not just one lecture or a handout pertaining to safety, but a continuous effort to think and practice safety both in laboratory operations and in everyday activities. The teacher should "sell" safety procedures to the students, require student competency, and enforce the practice of safety at all times. 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 provides both general and specific guidelines for activities frequently performed in the science classroom. Even though some chapters bear the names of specific subject areas in science, each chapter represents a topical grouping that may have information for all science teachers. 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 the work of the Science Safety Project Committee of the Maryland Science Supervisors Association. The committee has attempted to produce a Manual that communicates clearly the best that is currently known about safety practices in the science classroom and laboratory. While the committee assumes full responsibility for the contents

of the Manual, it also wishes to acknowledge with gratitude four principal resources used in producing the Manual:

- The Illinois State Board of Education, Center for Educational Innovation and Reform, Division of Intermediate and Secondary Level Support, which published the *Guidebook for Science Safety in Illinois*, 1995.
- The Virginia Department of Education, Division of Sciences, which published *Safety and Science Teaching*, 1997.
- The Maryland State Department of Education, Maryland School Science Safety Project, which published the *Science Safety Manual K-12* in 1985.
- Flinn Scientific, Inc., publisher of the annual *Chemical and Biological Catalog Reference Manual*.

In addition, the committee gratefully acknowledges two consultants and their organizations for their expert guidance throughout the process of developing the Manual: Robert Smoot, TekEd Associates, and Dr. James Kaufman, The Laboratory Safety Workshop. Mr. Smoot's and Dr. Kaufman's assistance was invaluable in helping to craft the comprehensive set of classroom safety guidelines presented in this Manual.

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.

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 a stimulating learning environment.*

I. Responsibilities

A Shared Responsibility for Safety

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 for safety items and ensure that they are in good condition.
 - See Chapter IV, Personal Safety Provisions.
3. Provide for regular inspections of the laboratory, and document inspection and maintenance of safety equipment.
 - See Chapter VI, Safe Handling of Equipment.
4. Ensure that a chemical hygiene plan is developed for the school.
 - See Chapter II.D.4, Federal Laws–Occupational Exposures to Hazardous Chemicals, and Appendix B, Chemical Hygiene Plan.
5. Ensure that only reagents included on the local school system's approved list of chemicals are used in the school laboratory with students.
 - See Chapter VII.A.1, Selecting Reagent Chemicals.
6. Comply with federal Hazard Communications Standard (Right-to-Know Law).
 - See Chapter II.D.2.b, Federal Laws–Hazard Communications Standard.
7. Ensure compliance with Maryland and Federal regulations for the disposal of excess laboratory reagents and laboratory waste.
 - See Chapter VII.C, Chemical Waste Strategies.
8. Establish a school safety committee that includes students and has a regular meeting schedule. Charge the committee with implementing appropriate classroom safety practices.
9. Provide a class size appropriate to the laboratory and in keeping with recommendations of professional societies.
 - See Chapter III.A, Class Size.
10. Ensure that all accidents are properly 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.

TEACHERS ARE RESPONSIBLE

FOR...

- **exercising good judgment in planning and conducting safe laboratory investigations.**
- **providing students instruction in safe laboratory procedures.**
- **providing supervision for all science activities.**
- **maintaining a written record of student safety instruction.**

B. Teachers' Responsibilities

1. Exercise good judgment in planning for and conducting student laboratory investigations.
 - a. Set a good example by observing all safety rules, wearing proper protective equipment, and being enthusiastic about safety.
 - b. Know the properties and hazards associated with each material used in a laboratory activity before the students carry out the procedure.
 - c. Ensure that all safety equipment is present in the laboratory and in good working condition.
 - See Chapter III, Safety Concerns and Emergency Laboratory Equipment, and Chapter VI, Safe Handling of Equipment.
 - d. Provide eye protection and other necessary personal protective equipment for students and instruct students in the use of such equipment.
 - See Chapter IV.A, Eye Protection Concerns.
 - e. Ensure that all containers are properly labeled with their contents and hazards.
 - See Chapter VII.A.5, Labeling of Stored Reagent Chemicals.
 - f. Comply with procedures in the school chemical hygiene plan.
 - See Chapter II.D.2.c, Federal Laws—Occupational Exposures to Hazardous Chemicals in Laboratories.
2. Provide student instruction in safe laboratory procedures in the classroom.
 - a. Provide comprehensive safety instruction for all students. Such instruction should include the location of all classroom safety equipment and safety procedures in a science classroom.
 - b. Have students sign a safety rules agreement.
 - See Appendix A, Safety Rules Agreement.
 - c. Instruct students in the use of safety goggles and other appropriate personal protective equipment.
 - See Chapter V, Safety Strategies in the Classroom.
 - d. Before each laboratory experiment, instruct students about the hazards associated with each laboratory reagent 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 V, 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 VII.B.3, Handling Chemicals—Spill Cleanup.
 - d. Dispose of laboratory wastes properly.
 - See Chapter VII.C.3, Disposing of Waste.
 - e. Return laboratory reagents 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 laboratory reagents you are working with.
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' Responsibilities

1. Read the safety rules. Discuss these rules with your child. 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.

II. Legal Aspects of Laboratory Safety **The Classroom Teacher as Responsible Party**

Several parties are potentially liable in the event of a charge of negligence in the science laboratory: the state, the school district, the school board, the school administration, and the teacher. Among these, the classroom teacher is most likely to be placed in the position of being the accountable person. It makes little difference whether you teach in the elementary classroom, middle school classroom, high school classroom, or outdoor education facility. The classroom teacher is ultimately responsible for the welfare of the student.

FOUR ELEMENTS OF LEGAL NEGLIGENCE

- **a legal duty of one person to another, as teacher to student**
- **a breach of this duty**
- **personal injury or monetary damage caused by the breach of duty**
- **legal breach judged to be proximate cause of injury or damage**

The classroom science teacher has basic responsibilities related to the legal concept of negligence. These include—

- 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. What Constitutes a Negligent Act?

Legal action against a teacher stems from the presumption that he or she is the expert in the laboratory and, as such, has the responsibility to ensure that exercises and operations are carried out in a prudent and safe manner. Liability exists to the extent that an injury can be shown to be the result of some action or inaction on the part of the teacher.

1. **Negligence:** A teacher may be deemed negligent if he or she allows a foolish or imprudent act to be committed; is careless in performing a demonstration; neglects a pre-existing unsafe condition; or neglects to warn of any hazards associated with an exercise, operation or demonstration.
2. **Degree of Negligence:** A teacher may be found fully, partially, or not at fault at all depending upon how the court judges culpability among the following:
 - a. The degree to which the teacher is judged to have been able to prevent or foresee the results of the action.
 - b. The student's injuries were a result of the student's own action.
 - c. The accident came about as the result of circumstances over which the teacher had no control or could not reasonably have been able to foresee.
 - d. The extent to which the teacher's actions were reasonable and prudent.

B. Negligence in Tort Law

1. Four elements must exist for a liability tort to be brought:
 - a. A legal duty of one person to another, as a teacher's duty to protect the students in his or her charge
 - b. A breach of this duty existing between two parties
 - c. Personal injury or monetary damages directly caused by the breach in legal responsibility
 - d. Legal breach of responsibility judged to be the proximate cause of the injury or damage
2. Such a breach may arise in one of three ways:
 - a. *Misfeasance*: the defendant acts in an improper manner.
 - b. *Nonfeasance*: the defendant did not act at all when he or she had a duty to act.
 - c. *Malfeasance*: the defendant acts with a bad motive or inflicts deliberate injury.

C. Avoiding Negligent Acts

The following steps are recommended to avoid negligence and forestall claims of negligence. These actions must be documented in case of future legal action. This documentation could include such items as a signed rules agreement, results of a safety quiz, pre-laboratory tests with safety questions, a plan book with notation of the safety rules covered for each laboratory activity on the day the activity was done, safety rules written into a notebook prior to performing the exercise or operation, and safety rules clearly indicated on any laboratory instruction sheets given to the students.

A reasonable and prudent teacher –

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.
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.

D. Federal Laws

The design, construction and operation of elementary and secondary school science classrooms and laboratories are affected by a number of federal laws and the regulations of several federal agencies. Administrators and teachers must be aware of the requirements imposed by these laws and regulations. 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)

Public schools are required to comply with provisions of the Americans with Disabilities Act of 1990. Students with disabilities are entitled to a level of laboratory experience appropriate to the individual student.



URL 3

► See the publication of the Committee on Chemists with Disabilities, American Chemical Society, *Teaching Chemistry to Students with Disabilities*.

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.



URL 1

Nevertheless, the prudent teacher will conduct the science classroom in such a manner that the regulations are followed by all occupants. Following OSHA precautions for all classroom or laboratory occupants is good safety practice. Such practice may also help to establish a *prima facie* defense in the event of a liability litigation.



URL 66

a. **Bloodborne Pathogens.** Concerns about workplace exposures to blood-borne pathogens led the Occupational Safety and Health Administration (OSHA) to issue regulation 29CFR 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 IX.D.1.d, Body Fluids and Bloodborne Pathogens.

b. **Hazard Communication Standard (Right to Know).** In 1983 the Federal Hazard Communication Standard (29CFR 1910.1200) became law. Basically, this law requires employers whose employees use toxic substances to provide these employees with (1) material safety data sheets (MSDS) that describe the properties, safe handling, and health hazards of the toxic materials; (2) labeling of all toxic substances with product name and a hazard warning; and (3) annual training on the hazards of toxic substances, safe handling procedures, and how to read MSDS.

c. **Occupational Exposures to Hazardous Chemicals in Laboratories.** This legislation (29CFR 1910.1450) requires all employers who are engaged in 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. However, this standard is based on the assumption that safety experts agree on a set of standards and practices for laboratory work that should be integrated into the chemical hygiene plan. This body of knowledge becomes the standard by which a teacher is judged for negligence.

3. Environmental Protection Agency (EPA)

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



[URL 1](#)



[URL 30](#)

4. Department of Transportation (DOT)

Whenever reagent chemicals or hazardous wastes are transported (except between buildings of a single campus), the materials must be packaged in accordance with DOT regulations. Sections 171-77 of 49CFR contain information relevant to school science programs.



[URL 1](#)



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III. Safety Concerns and Emergency Laboratory Equipment

Making the Laboratory a Safe Learning Environment

Students need to do science, not just read about science. As an outcome of inquiry-based 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 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 reagents 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. Teachers and administrators should be aware of national and state recommendations regarding class size in science and work collaboratively to create a safe laboratory environment.

SAFE SCHOOL LABORATORIES HAVE . . .

- **adequate work space for students and teachers.**
- **clearly marked emergency evacuation routes.**
- **master gas and electric cut-offs.**
- **properly maintained safety equipment.**
- **signs and labels to identify safety equipment.**

1. Recommendations of Science Organizations

- a. Major science education organizations offer the following recommendations:

The National Science Teachers Association (NSTA), National Association of Biology Teachers (NABT), and National Science Education Leadership Association (NSELA) are in agreement that the maximum number of students a single teacher can supervise properly in a science classroom is 24. The Association for Science Education calls for a maximum class size of 20 for students aged 5-16 and a maximum of 14 students over 16 years of age.

These recommendations are supported by studies reported in *Third Sourcebook for Science Supervisors*, NSTA, 1988, stating that science classes should be at 24 students per class with a maximum of 30. One study cited in that publication concludes that a safe science class size contains no more than 22 students. In 1990, the National Science Teachers Association adopted a position statement on laboratory science that stated the number of students assigned to a science class should not exceed 24.



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- b. *The Third Sourcebook for Science Supervisors*, NSTA, 1988, also states that the accident potential for a science class increases when the number of square feet per student falls below 41.
- c. *Pathways to the Science Standards – High School*, NSTA, 1996, recommends 45 square feet per student for a combination science laboratory/classroom. Because effective science instruction integrates seatwork with laboratory experiences, it is important to maintain approximately 40 to 50 square feet per student in the science classroom.
- d. The Maryland Science Supervisors Association position statement *Class Size Recommendations for Safe and Effective Science Education*, 1999, expresses support and agreement with the recommendations of NSTA, NABT and NSELA.

2. State Criteria

Many states have instituted specific criteria for the number of students and/or the allocation of space per student in a science classroom.

- a. **Space Allocations.** State space allocations per student in science classrooms:
 - (1) *Vermont*: state code calls for 50 square feet/student.
 - (2) *California*: State Administrative Code requires 54 square feet/student.
 - (3) *Maryland*: The State Department of Education recommends 45 square feet/student (*Science Facility Design Guidelines*, 1994).
- b. **Students Per Classroom.** Many states have established recommendations on the maximum number of students in each science classroom:
 - (1) Five states recommend a maximum of 24 students per science classroom
 - Florida, New Hampshire, Oklahoma, Texas, and Wisconsin.
 - (2) Two states recommend a maximum of 28 students per science classroom
 - Georgia and Maryland.
 - (3) One state recommends a maximum of 15 students per laboratory
 - Iowa.
 - (4) One state recommends a maximum of 20 students per classroom
 - Wyoming.
 - (5) One state recommends no more than two students per laboratory station
 - Minnesota (1989 science laboratory safety law).



3. Professional Safety Organizations

- a. A 1992 survey of state laws and guidelines on science class size found the following:
 - (1) One state had enforceable legislation regarding laboratory class size
 - Florida.
 - (2) 20 states have guidelines that either set a maximum class size of 25 or fewer or base student limits on the size of the classroom.

- (3) Class size is part of the negotiated contract in several states.

(Marilyn Steele, Paul Conroy, and James Kaufman, "There's No Safety in Numbers - Class Size and High School Laboratory Safety - A survey of State Legislation and Guidelines for Action at Local Levels," 1992, The Laboratory Safety Workshop, 192 Worcester Road, Natick, Mass 01760)

- b. Building Officials and Code Administrators (BOCA) International specifies a maximum occupancy load of 50 square feet per student in a science laboratory (May 24, 1999, interpretation of Section 1008.1.2 of BOCA National Building Code, 1996).
- c. The National Fire Prevention Association (NFPA) also specifies a maximum occupancy load of 50 square feet per student in a science laboratory (Section 10-1.7.1 of NAPA Life Safety Code, 1997).



These regulations and recommendations from professional organizations identify clear limits on space allocation and the numbers of students per classroom. Adherence to the above guidelines allows for a safe learning environment for students and teachers in science laboratories while facilitating effective, "hands-on" science activities.

B. Facilities

1. Emergency Evacuation Route

Emergency evacuation routes should be established for each classroom, and students instructed in evacuation plans. The plans should be a part of the chemical hygiene plan.

2. Master Gas and Electric Cut-offs

- a. Master gas and electric cut-offs should be readily accessible, preferably outside the classroom.
- b. In the event of a fire or electrical accident, shut off the gas and electricity in the laboratory.

3. Emergency Communication

Classroom teachers should be able to use a telephone or intercom to contact administrators or the school nurse in the event of an emergency.

4. Signs and Labels

The following types of 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
- f. Clearly label foodstuffs intended for laboratory exercises: *NOT FOR HUMAN CONSUMPTION.*
- g. Location signs for:
 - Fire extinguishers
 - Fire blankets
 - Eyewash station
 - Safety shower
 - Spill kits
 - Goggle cabinet
 - Exits
 - Waste containers (e.g., chemical, broken glass)
 - Master gas and electric cutoff

5.. Teaching Students with Disabilities

Science laboratories, like other school facilities, should be accessible and safe for students with disabilities. The American Chemical Society manual, "Teaching Chemistry to Students with Disabilities," is a good guide to ensuring that students with disabilities receive the appropriate laboratory experience.



C. Fire Safety and Fire Control

In the event of a fire you must decide if you can fight the fire or need to evacuate the building and call the fire department. The decision whether or not to fight a fire will depend on many things, including the size and location of the fire, your confidence in dealing with the situation, and your training in fire fighting. Remember that the personal safety of the building's occupants must always be the first priority.

1. Extinguishing Fires

a. Small Fires

- (1) If a person's clothing or hair catches on fire, have the person stop, drop, and roll on the floor to suffocate the flame. Do not use fire extinguishers on people.
- (2) In the case of a small fire that can be easily extinguished, the teacher must take prompt action to either treat as a "serious" fire and evacuate the classroom or extinguish the fire using classroom fire management equipment.

- (3) A fire in a small vessel can usually be extinguished by covering the vessel with a nonflammable material such as a fire blanket. Remove nearby flammable liquids to avoid the spread of the fire.

b. Serious Fires

In the event of a serious fire, follow these steps:

- (1) Evacuate everyone from the room.
- (2) Sound the fire alarm and notify the school administration.
- (3) Shut off master gas and electrical power, if possible.
- (4) Close windows and doors, if possible.
- (5) Fire fighters should be informed of the potential added hazards of reagents or other materials present in the classroom or laboratory. A current inventory of hazardous materials should be available outside the work area. Posting the National Fire Protection Association (NFPA) diamond, providing emergency information about the room's contents, is the best way to give fire fighters the information they need as they enter the area.



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c. Exceptions

In certain circumstances where a fire may be extinguished through quick and skillful action, a teacher or other school staff *trained in the use of a fire extinguisher* may attempt to put out a fire before it spreads to a larger area. Such action must be taken from a position that allows for quick escape. It is important to understand that even small fires cannot always be extinguished easily.

2. Fire Extinguishers and Their Use

Class	To Fight Fires Involving:	Method to Extinguish
A	wood, paper, cloth	Use water or dry chemical extinguisher.
B	gasoline, alcohol, paint oil, or other flammable liquids	Smother by using carbon dioxide or dry chemical extinguisher.
C	fires in live electrical equipment	Cut off power to electrical equipment. Use multiple purpose (ABC) or carbon dioxide fire extinguisher.
D	metals (Na, K, Mg, etc.)	Scoop dry sand onto fire.

An easy way to remember which class of extinguisher to use is to think of Class A - ash (solid), B - boil (liquid), and C - charge (electrical).

3. Fire Blankets

- a. Fire blankets of flame-retardant wool 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. For clothing fires, fire blankets should be used with caution. The best method is the “stop, drop and roll” method.

D. Safety Equipment**1. Eyewash Fountains**

Eyewash fountains are essential in areas where reagent chemicals are used. Caustic chemicals can damage the eye within seconds of contact. The eyewash fountain should –

- treat both eyes simultaneously.
- provide a gentle flow of water for at least 15 minutes at 0.40 gallon per minute minimum (ANSI Z, 358.1-1998).
- be accessible within 10 seconds from the time of injury.
- leave both hands free to hold eyelids open.
- be accessible for all students.



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The National Safety Council recommends that all plumbed eyewashes be flushed for three minutes a week to reduce the risk of eye infections. A maintenance record should be maintained.



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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 growth of microorganisms.

2. First Aid

- a. Every school should have a safety and first aid plan.
- b. Each laboratory should have a first aid station for providing basic first aid and stabilizing students who will be transported to a medical facility. The stations should have the following:
 - A standard first aid kit stocked according to school policy and recommendations of the school nurse

- Emergency phone numbers posted in a conspicuous place: numbers for an on-call physician; emergency, fire and police services; poison control; and medical facilities

3. 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 provide no protection at the back and sides. If possible, the shield should be attached to the surface on which it is placed (perhaps by clamps).

4. Safety Showers

A safety shower should be available in every laboratory. The shower is used to wash hazardous chemicals from the skin. The Emergency Eyewash and Shower Equipment Standard (ANSI Z, 358.1-1998) requires that an emergency shower be located no more than 10 seconds in time nor greater than 100 feet in distance from the site of the emergency, and provide a minimum flow of 30 gallons per minute. Deluge showers are intended for major spills and should provide an uninterrupted flow of water until the valve is turned off. The shower should be tested and the tests recorded periodically in accordance with the school safety plan or as directed by the manufacturer.



A hand-held sprayer with a six-foot hose is a good 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.

5. Sanitation of Safety Goggles

If safety goggles are used by multiple classes, sanitize them between each class. Commercially available Ultraviolet (U-V) cabinets include those that hold up to 30 goggles and take 5-15 minutes per cycle.

A lower-cost option is to use a chemical disinfectant specifically made for disinfecting goggles. Household bleach and disinfectants can be used by diluting according to directions on the label.

6. 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, pails, bags, and dust pans
- Appropriate personal protective equipment

E. Ventilation

1. Room ventilation

Adequate ventilation is important in any room in which reagent chemicals are used or stored. According to *Prudent Practices for the Laboratory*, the air in a science laboratory should be changed a minimum of six times per hour.



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Chemical storerooms should have ventilation adequate to keep atmospheric levels of chemicals below their hazardous limits. As with room ventilation, a minimum of six air changes per hour are recommended.

2. Fume Hoods

Fume hoods are the most important equipment used to protect teachers and students from exposure to hazardous chemicals and agents used in the laboratory.

a. **Velocity.** A face velocity of 80 fpm (the average velocity of air drawn through the face of the hood) should effectively remove fumes produced within the hood, conditional on proper placement and use.

b. Rules for Using Fume Hoods

- (1) Do not store reagent chemicals in a fume hood.
- (2) Fume hoods must be inspected for proper use. Devices are available to measure face velocity.
- (3) Keep the sash at its most efficient level.
- (4) 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.
- (5) If possible, the hood should be located away from windows, doors, and areas of heavy traffic to avoid drafts.

IV. Personal Safety Provisions

Protecting Students' Eyes and Bodies

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 protection.

A. Eye Protection Concerns

Annotated Code of Maryland, Education Section (GED) Article 7-407, covers the legal requirements for providing eye protection in the laboratory. In addition to specifying some requirements for career and technology classrooms, the article states that "Each student and teacher in a school...shall be required to wear an industrial quality eye protective device at all times while working in...[a] chemical or combined chemical-physical laboratory that involves any caustic or explosive chemical or hot liquid or solid." In applying the legal standards, a "better safe than sorry" attitude is recommended.

SAFETY IN THE SCHOOL LABORATORY REQUIRES . . .

- **the availability and, when necessary, the wearing of aprons and gloves.**
- **care in preventing clothing or long hair from becoming a hazard.**
- **special attention to prevent eye damage by wearing appropriate goggles.**



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1. Goggles

- a. Teachers, students, and visitors should wear chemical splash safety goggles at all times during laboratory work since the student – and sometimes even the teacher – cannot reliably judge the presence of risk. The teacher has the responsibility to train students in the proper use and care of goggles.
- b. Chemical splash safety goggles should be used as the standard protective eyewear. Such goggles should fit the face surrounding the eyes snugly to protect the eyes from a variety of hazards. Ventilation of the goggles should be adequate but well protected from splash entry. Safety glasses are not an acceptable substitute for chemical splash safety goggles because they provide protection from impact only and not from chemical splashes.
- c. The eye protectors should meet the requirements of the American National Standard Z87.1-1989, Practice for Occupational and Educational Eye and Face Protection.
- d. 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 which 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



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rubbed into the lenses. Glass lenses with surface scratches should be replaced since the hardened glass has thus been weakened.

- e. Chemical splash safety goggles should never be left with the lenses in contact with hard surfaces such as table tops.
 - f. Chemical splash safety goggles should not be carried unprotected and in the same pocket with other objects such as pencils or files. It is good practice to keep goggles in a case when they are not being worn.
 - g. Goggle sterilization cabinets should be located in the laboratory work area.
- See Chapter XI.G.3, Laser Guidelines, for information on eye protection when working with lasers.

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 his or her eyes, the contact lenses must be removed immediately and the eyes flushed with water.

B. General Guidelines for Dress in the Laboratory

1. Loose fitting, frilly, or highly flammable clothing should not be worn in the laboratory. Ties should be tucked into shirt or removed.
2. Sandals, open-toed shoes, and shoes with canvas or mesh uppers should not be worn in the laboratory.
3. Long hair and loose clothing or jewelry must be confined when working in the laboratory.

4. Finger rings should not be worn while working with reagent 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. Protective Apparel

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, very 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 different types of gloves are commercially available. Consult a laboratory supply catalogue for descriptions of the various types available and their specified uses.
 - d. Before each use, gloves should be inspected for discoloration, punctures, and tears.
 - e. Before removal, gloves should be washed appropriately. (NOTE: Some gloves, including those made of leather and polyvinyl alcohol, are water permeable.)
 - f. Glove materials are eventually permeated by chemicals. However, they can be used safely for limited time 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.
 - g. Gloves should be replaced periodically, depending on frequency of use and permeability to the substance(s) handled.

3. Laboratory Coats

Laboratory coats are intended to prevent contact with dirt 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.



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V. Safety Strategies in the Classroom

Knowledge and Common Sense Are Keys to Safety

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 students 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.

TEACHERS MAKE LABORATORIES SAFE BY . . .

- **teaching students how to conduct investigations safely.**
- **making sure that safety equipment is functioning and available.**
- **being a model for obeying safety rules.**
- **supervising students to ensure that they obey safety rules.**
- **documenting safety instruction.**

Teaching students the proper way to handle materials in the school laboratory should also help them learn 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. Students will not take safety rules seriously unless the teacher obeys and strictly enforces these rules.

The successful science safety program begins with the teacher's belief in safety as an integral part of science instruction. A demonstration lesson is a good opportunity for the teacher to illustrate the proper use of safety equipment and practices. Maryland law requires approved chemical splash safety goggles for certain laboratory activities and does not permit exceptions, including classroom visitors. Teachers should advise visitors of safety precautions before they enter the laboratory area.

A. Safety Guidelines for the Teacher

1. Safety Rules

Teachers should develop a set of safety rules for students. Specific sanctions should be identified for student violations of the rules. The rules and sanctions should be spelled out in a rules agreement that is signed by the students and parents. Signed copies of the agreement should be kept on file by the teacher. This is not a legal document but can help make students aware of their responsibility for safety and the seriousness of the matter. The school administration should give written acknowledgment of its support of the rules

agreement and sanctions.

►See Appendix A, Safety Rules Agreement.

2. Safety Quiz

Teachers should give students a safety quiz to assess their understanding of safety rules and procedures.

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.

4. Posters and Signs

Posters highlighting your safety rules and techniques are effective reminders to students and all who enter the laboratory.

5. Handling Reagents

Teachers can reduce students' exposure to harmful chemicals by selecting those that pose a minimum risk. Teachers are responsible for training students in the proper handling of reagent chemicals. Training should include the importance of –

- safe storage of chemicals and proper disposal of chemical waste.
- using a ventilation (fume) hood for any experiment that may generate hazardous or irritating fumes.
- smelling substances by wafting the fumes toward the nose with a cupped hand.
- pouring corrosive reagents from their containers by using a stirring rod. If chemicals drip down the sides, clean the bottle before picking it up.
- taking care with reagent 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 into the target container.

►See Chapter VII.A.4, Chemical Storage; VII.C, Chemical Waste Strategies; and

VII.B, Handling Reagent Chemicals.**6. Safe Laboratory Protocols**

- a. Teachers should circulate among students to monitor students' work and ensure that they can respond to emergencies quickly.
- b. Teachers should stay in the laboratory at all times when students are working and not let students work alone or unattended.
- c. Teachers should make sure their students understand instructions before the students begin work. Teachers should inform students about the special hazards and precautions associated with specific experiments.
- d. Teachers should allow sufficient time for student performance. Rushing students often causes accidents.

7. Knowledge of 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 Material Safety Data Sheets (MSDSs) must be kept in alphabetical order. 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 prior to 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.

►See Appendix C, MSDS: Explanation and Samples.

8. Safety Practices

Teachers should follow current safety practices. The substitution of a less hazardous chemical in an experiment can improve laboratory safety and minimize the need to dispose of hazardous waste (See Chapter VII.C.1.a, Alternative Substances.) Teachers must be careful when using older books and laboratory manuals as sources of experiments because laboratory practices have changed in recent years. As needed, teachers should consult science journals and publications to keep current on safety techniques.

9. Access to Chemicals

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 reagents in the classroom during an activity. Students should have access only to the chemicals and quantities needed. Locking the laboratory when it is not in use is important to prevent

unauthorized experimentation or theft.

10. Good Housekeeping and Safe Storage

Good housekeeping can make a significant contribution to safety in the laboratory. Teachers can promote good housekeeping habits by –

- insisting on proper laboratory cleanup from the first laboratory session. Proper cleanup includes keeping all laboratory areas, sinks, and implements clean, neat, and orderly.
- establishing a procedure for “checking” students out of 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.
- holding each student responsible for cleaning up his or her own area and materials. Teachers and students should help each other with cleanup.
- assigning individuals or teams to take charge of common areas and by checking on the return of items used in the laboratory activity.
- scanning common 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.
- storing glassware on drying racks or open shelves. Allowing water to evaporate saves time and paper towels.
- including time for cleanup in the regular lesson schedule.
- labeling shelves and trays so students can tell where to return materials.
- having students return to their seats after cleanup, scanning the laboratory and equipment, and not dismissing students until all is in order.
- complimenting students if things look good or cleanup was performed quickly and efficiently.
- 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.
- 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.

- making sure that cabinets and drawers are closed when not in use.
 - arranging seats to allow safe and quick exiting 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.
 - making sure that wastes are deposited in appropriate receptacles.
- See Chapter VII.C.3, Disposing of Waste, for removal procedures.

11. Accidents

Be alert for 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 below Chapter V.C.2, Responses to Specific Types of Injuries.
►See also Chapter III, Safety Concerns and Emergency Laboratory Equipment, and Chapter VI, Safe Handling of Equipment.

B. Safety Rules for Students

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

- Know the location of safety and first aid equipment, including fire extinguisher, safety shower, fire blanket, and eye wash.
- Do not engage in horseplay or other acts of carelessness.
- Dispose of wastes properly. Do not put matches in the sink. Broken glassware should be discarded in proper containers.
- Never eat or drink in the laboratory.
- Never drink from laboratory glassware.
- Notify the teacher when you observe 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.
- If at any time you do not understand an experimental procedure, ask your teacher to explain the procedure.
- Always 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 reagents to the stock bottle; discard any excess according to approved procedures.
- Never mix chemicals together 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 IV, Personal Safety Provisions, and Chapter VI, Safe Handling of Equipment, for specific laboratory and equipment handling rules.

C. Responses to Injuries

1. General Procedures

Emergency procedures should be established at the beginning of the school year and conspicuously posted in your classroom.

- 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 school system procedures.
- b. Teachers should strongly encourage parents or guardians of injured student to seek follow-up care for the student from medical specialists.
- c. Teachers should never have students go for medical assistance by themselves. In circumstances where it is appropriate for students to seek medical assistance, always have another student accompany the injured student.
- d. Safety equipment should be located in a prominent place and clearly identified with signs.

►See Chapter III.B, Facilities, and Appendix C, MSDS: Explanation and

Samples, for additional information on emergency procedures.

2. Responses to Specific Types of Injuries

- a. *Bleeding.* After putting on a pair of latex gloves or 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 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 MSDS 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 IV.A, Eye Protection Concerns.
- 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 large 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 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.

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 be required to 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.

VI. Safe Handling of Equipment

Avoiding Accidents by Using Equipment Safely

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 (Pyrex® brand or Kimax® brand).

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
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- c. For containing reactive chemicals during experiments:

beakers	flasks
test tubes	watch glasses
test plates	

- d. For transferring liquids and gases:

glass tubing	funnels
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- e. For measuring temperature:

thermometers

TEACHERS AND STUDENTS AVOID ACCIDENTS

BY . . .

- **using the proper equipment.**
- **making sure the equipment is clean and in good working order.**
- **receiving instruction in the proper use of all equipment.**
- **practicing the proper use of equipment.**

3. Cleaning

Keep glassware clean.

- a. Clean immediately after use. The longer glassware sits, the harder it is to clean.
- b. Use laboratory-grade detergents 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 defect 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 should be fire-polished.
- 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. "Frozen" Glass

Be careful with glassware that is "frozen." Only teachers, wearing goggles and gloves, should try to release the "frozen" glassware. If this fails, discard the glassware. Some common cases of "frozen" glassware are:

- a. nested beakers that have been jammed together.
- b. stoppers that cannot be removed from bottles.
- c. stopcocks that cannot be moved.

6. Hot Glass

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

- a. Breaking. Use gloves or towels to protect hands when breaking glass tubing. Use goggles to protect the eyes. Here are the steps for properly breaking glass tubing.
 - (1) Scratch the glass once with a file or score.
 - (2) Wrap the glass in a towel.
 - (3) Place the thumbs together opposite the scratch.
 - (4) Pull and bend in one quick motion.
 - (5) 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:
 - (1) 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.
 - (2) When the glass is soft and pliable, remove it from the flame and quickly bend to the desired shape. Results will improve with practice.
 - (3) 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 container 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. Corks 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

- 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. Alcohol Thermometers

If glass thermometers are being used, it is highly recommended that they be alcohol filled. Mercury thermometers should be phased out as quickly as possible. If mercury thermometers must be used for purposes of higher accuracy, it is recommended that Teflon® coated thermometers be used.

►See Chapter VIII.B.4, Mercury Spills.

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. Mercury thermometers should not be used in heated ovens where breakage might easily occur.
- f. Don't place thermometers where they are likely to roll or be knocked off a table. All thermometers should have anti-roll devices.
- g. 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 Gas Burners

- a. Make sure you know the location of the master gas shut-off valve.
 - b. Match the type of burner to the type of gas available.
 - c. Make sure all students know how to operate the burner safely.
 - d. Make sure there are no leaks in rubber hoses connecting the source to the burner.
 - e. Keep rubber hoses away from the flame
 - f. A soft rubber hose connection from a gas burner to the gas outlet is better than a semi-rigid, woven cover type connector, as this lessens the danger of tipping.
 - g. Use a ceramic-centered (not asbestos-centered) wire gauze under the object to be heated to distribute the heat evenly.
 - h. Use matches or lighters instead of strikers for lighting burners. Light matches or lighter before turning on the gas. Bring flame to the side of the top opening of the barrel while slowly turning on the gas.
 - i. Turn off the gas if the gas "flashes back" or burns at the burner base.
 - j. Do not lean toward or reach across a flame.
 - k. Never leave anything unattended while it is being heated or is reacting rapidly.
 - l. Remember that the gas burner barrel remains hot long after use.
 - m. If wing tops (flame spreaders) are used, allow time for these to cool before removing them from the gas burner.
 - n. Turn off gas valves before leaving work area.
2. **Safety Rules for Using Electric Hot Plates**
 - a. Use a hot plate with a smooth, clean surface.
 - b. Hot plates appear exactly the same whether hot or at room temperature. Always assume they are hot and act accordingly.
 - c. Keep the electrical cord of a hot plate away from water and the heating surface.
 - d. The cord of the hot plate should be checked periodically for frays and faults. Any hot plate with faulty wiring should not be used. It should be repaired or replaced immediately.
 3. **Safety Rules for All Heating Processes**
 - a. Never heat a closed container.
 - b. Never point the open end of a test tube toward anyone.
 - c. Never look into the open end of a heated test tube.
 - d. Test tubes should be held with a test tube holder and heated gently along

- the side, not at the bottom, to minimize superheating.
- e. Any set-up should be designed to allow for fast removal of the heat source.
 - f. 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

1. Refrigerators and freezers used for the storage of chemical reagents and/or biological materials should never be used for the storage of food.
2. Flammable materials should be stored in the flammable material cabinet and not in the refrigerator.
3. A sign should be placed on the refrigerator as a warning not to store flammable and other inappropriate materials inside.

F. Electrical hazards

1. Treat all circuits as though they were energized.
2. Make sure 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 a 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 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;
 - 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. Makes 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 the 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.

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.

1. Have proper carts available for transporting gas cylinders. Do not roll large cylinders around.
2. Use the proper tank and fittings designed for each gas. Your gas supplier will be able to help you with this.
3. Asphyxiation is the most subtle danger of working with compressed gases. Always use compressed gases in a well-ventilated area.
4. 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.
5. Keep electrical lines away from compressed gas tanks.
6. Keep gas tanks away from heat sources.

L. Microcomputers

1. Electric Shock.

The use of microcomputers in the science laboratory is increasing at a rapid rate. 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.

- a. When the internal electronics must be exposed to make connections, unplug the computer. Most computer circuitry operates on low voltage direct current, but higher A.C. and capacitors are present in the power

- supply as well as the VDT (Video Display Terminal).
- b. Whenever possible, students should only make connections to external connection ports (i.e., game paddle connectors, exposed edge connectors). Often it is possible to use low voltage extension cables from inside the computer to an outside location to reduce the risk of accidental shock while making connections.
 - c. Some applications require 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.

2. Ergonomics

Some study should be given to the physical arrangement of the keyboard, video display, and lighting. Muscle fatigue and eye strain can be reduced by the appropriate positioning and adjustment of these components.

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 work space 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 evolved, 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 III, Safety Concerns and Emergency Laboratory Equipment, and Chapter V, Safety Strategies in the Classroom, for related ideas on safety practices.

VII. Chemicals: Managing, Handling and Disposing

Safety in Ordering, Storing, Using and Disposing of Chemicals

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

Safe management of chemicals in the classroom requires that the teacher have adequate knowledge of the chemicals to be used and their interactions.

Information about these chemicals is available on the Materials Safety Data Sheets (MSDSs) for each chemical, in chemical catalogues, and on container labels. An Internet search under the keyword "MSDS" will yield information on websites that supply information on chemicals.
►See Appendix C, MSDS: Explanation and Samples.

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

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

A. Managing Reagent Chemicals

1. Selecting Reagent Chemicals

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

- a. A copy of the lesson plan for the proposed demonstration or laboratory exercise.
- b. Information supporting the following assertions:
 - Use of the substance is pedagogically sound.
 - The demonstration or laboratory exercise using the substance is an effective way to illustrate an important property, process or concept.

MAINTAINING CHEMICAL SAFETY

REQUIRES . . .

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

- No satisfactory substitute for the substance is readily available.
 - Adequate safeguards are in place to ensure proper use of the substance.
 - Students will be instructed in the proper handling of the substance (as indicated in the lesson plan).
- c. Information on the following to enable the supervisor to make an informed decision:
- the extent of exposure of students and the teacher to the chemical (including estimate of time to the nearest minute).
 - the age or maturity level of the students who will be exposed.
 - the recommended maximum levels of exposure set by regulatory and/or professional organizations.
- d. In considering a substance for use in the laboratory, teachers are advised to check hazardous materials lists available in print and on the Internet. Resources available include the following:
- The National Toxicological Program for lists of carcinogenic and reproductive toxins (teratogens and mutagens)
 - The National Research Council's *Prudent Practices in the Laboratory* (1995), Chapter 3, for lists of carcinogens, mutagens, teratogens, and highly flammable materials
 - The Oak Ridge Toxicology Information Resources Center's *Catalog of Teratogenic Agents*

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

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

► See Appendix H, Resources.

2. Ordering Reagent Chemicals

- a. Before ordering reagent chemicals, the teacher should–
- make sure the chemical is on the school system's list of approved chemicals.
 - be capable of assessing the hazards of chemicals.
 - be sufficiently knowledgeable to recognize requests from other teachers for nonessential chemicals.

- have a current inventory of existing chemicals.
► See Chapter VII.A.3, Chemical Inventory.
- b. Reagent chemicals should be ordered in quantities consistent with the rate of use.
- c. Reagent chemicals should be ordered in polyethylene bottles or plastic-coated bottles, if available, to minimize breakage, corrosion, and rust.
- d. For each reagent chemical used, ask the following questions:
 - Can proper storage be provided for the chemical?
 - Are the facilities appropriate for the use of the chemical?
 - Will the chemical or its end products require disposal as hazardous waste?
 - Is appropriate personal protective equipment available for safe use of the chemical or its end product?
 - Have persons who will handle and use the chemical been trained in handling reagent chemicals? Are they aware of the hazards?

3. Chemical Inventory

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



The chemical inventory record should-

- contain the date the inventory was conducted.
- identify chemical reagents by name and formula.
- specify the amount of each reagent present.
- indicate the storage location of each reagent.
- indicate the hazard of each reagent, using information from the Material Data Safety Sheet (MSDS) for each substance and the appropriate National Fire Protection Association hazard code.
► See Appendix E, NFPA Identification Codes, and Appendix C, Materials Data Safety Sheets (MSDS): Explanation and Samples.
- indicate the arrival date and quantity of all reagents received.



4. Chemical Storage

a. General Guidelines

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

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

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

b. Storage of Flammable and Combustible Liquids**(1) Definitions**

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

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

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

(2) Guidelines

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

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



URL 51

URL 66

- 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

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

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

5. **Labeling of Stored Reagent Chemicals**

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

a. **Purchased Reagent Chemicals**

All purchased reagent chemicals should be labeled with—

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

b. **Solutions.**

All reagents created in the laboratory should be labeled with—

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

B. Handling Reagent Chemicals

1. Dispensing Reagent Chemicals

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

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

a. Safety Guidelines for Dispensing Reagent Chemicals

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

b. Dispensing Flammable Liquids

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

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

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

2. Common Hazards

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

a. Corrosives

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

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

b. Flammables

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

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

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

c. Oxidizers/Reactives

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

- (1) *Oxidizers*. An oxidizing agent is any material that initiates or promotes combustion in other materials, either by causing fire itself or by releasing oxygen or other combustible gases.
- (2) *Reactives*: Reactives include materials that are pyrophoric ("flammable solids"), are water reactive, form explosive peroxides, or may undergo such reactions as violent polymerization.

d. Toxins

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

(1) Methods of Toxins Entering the Body:

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

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

(2) Types of Toxins

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



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

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

e. **Mercury**

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

- (1) Mercury and its compounds should never be found in the elementary or middle school.
- (2) In high schools, mercury should be used only under special circumstances. Mercury is acceptable in high school only if all four of these criteria are met:
 - No substitute is available that will provide the degree of accuracy required for the operation.
 - The teacher has obtained prior approval from the science supervisor.
 - All persons in the laboratory working with mercury or an instrument containing mercury wear chemical splash safety goggles, full face shields, aprons, and adequate clothing to prevent skin contact.
 - Access to mercury or any instrument containing the element is restricted by keeping source and instrument under lock and key except when in use.

3. Spill Cleanup

a. **General Notes on Chemical Spills**

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

- See Chapter VII.C, Chemical Waste Strategies.
- After floor spill has been thoroughly cleaned up in the appropriate manner, the area should be mopped dry to minimize the risk of slipping and falling.

b. Spills that Constitute Fire Hazard

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

c. Other Spills

- (1) Use an absorbent material to neutralize the liquids. Materials include:
 - for acids, powdered sodium bicarbonate
 - for bromine, sodium thiosulfate solution (5-10%) or limewater
 - for organic acids, halides, nonmetallic compounds, or inorganic acids, use slaked lime and soda ash
 - or general spills, use commercial absorbents or spill kits, small particles of clay absorbents (kitty litter), or vermiculite
- (2) Wear rubber gloves and use a dustpan and brush. Clean the area thoroughly with soap and water, then mop dry.
- (3) Aromatic amine, carbon disulfide, ether, nitrile, nitro compound, and organic halide spills should be absorbed with cloths, paper towels, or vermiculite and disposed of in suitably closed containers.

4. Mercury Spills

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

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

C. Chemical Waste Strategies

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

1. Minimizing Waste

a. Alternative Substances

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

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

b. Microscale Laboratories

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

c. **Classroom Demonstrations**

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

d. **Coordinate Laboratory Work**

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

2. Waste Storage Prior to Disposal

- a. All waste should be stored in properly labeled containers. The label should contain the date, type of waste, and any other pertinent information required by the disposal company.
- b. Waste should be segregated to avoid unwanted reactions and to allow for cost-effective disposal.
- c. Waste should be stored in closed containers except when additional waste is being added.
- d. Each school science department should maintain a central, secure waste storage area.

3. Disposing of Waste

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

a. **Classification of Hazardous Waste**

The Environmental Protection Agency classifies wastes as:

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

b. Classroom Management

- Make disposal options a part of all laboratory instructions for students. For each chemical waste produced, instruct students as to the appropriate disposal, including disposing of the substance in a disposal container or down the drain.
 - See Chapter VII.C.3.c, Drain Disposal.
- Place all laboratory waste in a properly labeled container. The label should contain the date and type of waste.
- Immediately following the laboratory activity, place the waste containers in a secure location until the containers can be removed to the central storage area.
- Some chemical wastes may be recycled. Teachers should seek guidance on recycling from local safety officers or other knowledgeable administrative staff.

c. Drain Disposal

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

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

Table continued on next page

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

- The following organic compounds can go into a drain:

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

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



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

d. Compounds Not Suitable for Drain Disposal

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

VIII. Outdoor Safety – Field Studies

Success Through Good Planning and Sound Procedures

Taking students on field studies can be a valuable, positive addition to the science program, especially for younger children and/or in an environmental curriculum. An effective field study is most valuable when educational objectives are clearly identified and the activities are constructed or designed to achieve those objectives. When the study is well planned and organized, the possibility of accidents occurring is greatly 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' permission for their children to participate in studies off the school grounds. Have students take a written description of the trip home to their parents. Include in the information the types of clothing to be worn, safety precautions to be taken, and a parental permission form.
- c. On the day of the 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 field study for all students based on any physical disabilities, 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. Make appropriate arrangements with the special education staff, school nurse, and/or parents for students with special needs.
- b. Arrange for transportation to the site using transportation approved by the local school system.
- c. 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.

FIELD STUDIES ARE VALUABLE EDUCATIONAL EXPERIENCES WHEN TEACHERS . . .

- **keep student safety in mind.**
- **establish and enforce rules for safe student conduct.**
- **plan field studies by visiting the site, establishing emergency procedures, and obtaining parental permission.**
- **ensure that specimen collections are legal and serve valid educational purposes.**

- d. Arrange for parents or other responsible adults to assist with supervision as appropriate.

4. Rules

- a. Follow the rules your school or school system has established relating to trips outside the school. Make sure students know whether or not regular school rules apply during the field study off campus. Inform students of any specific school rules that apply to field trips.
- b. Before each trip, establish rules for safe student conduct and explain the rules to all participating students and adult supervisors.

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

6. Precautions and Emergencies

Before the field study, some precautionary measures should be taken to ensure a safe trip. These measures include the following:

- a. Based on the pre-trip survey, map the safest passage through the area.
- b. Instruct the students in S
 - safe methods of movement through the study area, with special caution given to the transport of equipment

- recognition and avoidance of poisonous plants and animals.
- the need for and use of appropriate shoes and other clothing.
- safe methods for working on or near bodies of water (including the appropriate use of the buddy system and life jackets).

Note: Basic water safety rules may be found in first-aid, Scouting, and Red Cross publications.



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- the proper use of equipment, including the use of chemical splash safety goggles (or other eye protective devices).
- proper use and handling of chemicals used for water and soil testing.

c. Prepare for emergencies in the following ways:

- Determine a method for contacting the school office in the case of an emergency.
- Be prepared to follow the school or school system's emergency procedures in the event of an accident.
- Maintain up-to-date medical information and emergency telephone numbers for each student.
- Be aware of any medications students are currently taking and determine if the medications will need to be taken while on the trip.
- Be sure that first-aid kits are readily available and check the kits to make sure they contain the essential items.
- 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.
- Be prepared to provide appropriate means for transporting an injured student to receive treatment.



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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
 - (1) Require students to wear chemical splash safety goggles whenever they use laboratory reagents or liquids. 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.

- See Chapter IV.A, Eye Protection Concerns.
- (2) If students share goggles, the goggles must be cleaned and disinfected after each use.
 - See Chapter III.D.5, Sanitation of Safety Goggles.
- b. Collecting Organisms

Field study should not include the collection of organisms unless a valid educational purpose is served by the collection and adequate research has been done to ensure both the safety and legality of the collection.

 - See Chapter IX, Biology and Environmental Science.
- 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.

IX. Biology and Environmental Science

Recognizing and Controlling Hazards

Biology and Environmental Science teachers and their students face a wide range of potential hazards. In addition to chemical reagents, there are the 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 biology laboratory.

► See Chapter IV, Personal Safety Provisions.

1. Body and Clothing Protection

► See Chapter IV.C, Protective Apparel.

2. Eye Protection

► See Chapter III.D, Safety Equipment; Chapter IV.A., Eye Protection Concerns; Chapter VI.J, Cryogenics; and Chapter VIII.B.2.a, At the Site – Goggles.

3. Hand Protection

- Rubber or plastic gloves should be provided for students to use when handling preserved organisms.
- Anyone with breaks in the skin or unhealed scratches should wear rubber or plastic gloves when working with preserved organisms.
- Heavy rubber or leather gloves should be provided for use when handling live animals as protection against animal bites and scratches.
- Soap and water 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 IV.C.2, Protective Apparel – Gloves.

4. Respiratory Protection

► See Chapter III.E, Ventilation, and Chapter IV.C.4, Respiratory Protection.

BIOLOGY LABORATORIES ARE SAFE

WHEN . . .

- **student safety is considered in determining an activity's value.**
- **proper laboratory techniques are taught and practiced.**
- **physiological measurements are neither stressful nor invasive.**
- **care is taken in selecting and using reagents.**
- **specimens are handled according to professional guidelines.**

B. Classroom/Laboratory Safety**1. Equipment**

► See Chapter VI, Safe Handling of Equipment.

2. Chemical Reagents**a. Stains**

Staining is an important part of biology studies. Teachers must obtain the appropriate Material Safety Data Sheets (MSDSs) for all staining reagents and follow the stated precautions.

► See Appendix C, MSDS: Explanation and Samples.

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

► See Chapter VII. Chemicals: Managing, Handling and Disposing.

3. Dissections

- a. Students should wear chemical splash safety goggles and aprons.
- b. Long hair, loose clothing, and jewelry should be secured.
- c. Rubber or plastic gloves should be provided.
- d. Students with breaks in the skin should wear gloves or be excused from laboratory.
- e. The room should be adequately ventilated during dissections, particularly when preserved specimens are used.
- f. Care should be used in the handling of all dissection instruments.
- g. Dissecting pans or trays should be provided.
- h. Scalpels or single-edged razor blades should be used. Single-edge razor blades with a rigid, reinforced back are preferred.
- i. 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.

- j. It is important to secure the specimen in or to the pan or tray. Dissection pans may be used.

► See Chapter IX.D.2.d, Zoology: Animal Considerations--Dissection.

4. Heating and Sterilization Devices

- a. **Autoclaves/Dry Heat Sterilizers/Pressure Cookers.** Autoclaves and dry heat sterilizers are preferred. All precautions in dealing with electrical equipment should be followed. A pressure cooker may be used as a substitute, but it involves greater attention due to the hazards involved in a non-automated system.

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

Autoclaves, heat sterilizers, and pressure cookers should be run only by the teacher or professional aide or by the student aide if he/she is 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.

In using a pressure cooker, check the safety valve before pressure is built 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. Heat sterilizers are preferred over pressure cookers.

► See Chapter XI.B, Electrical Hazards, and Chapter IX.C.4, Decontamination and Disposal of Materials.

- b. **Gas burners.** When heating materials at high temperatures, a gas burner may be used.

► See Chapter VI.D.1, Safety Rules for Using Gas Burners.

- c. **Hot plates.**

► See Chapter VI.D.2, Safety Rules for Using Electric Hot Plates.

- d. **Water baths.** Water baths can be useful in a biology laboratory. The baths must be well maintained for safe operation.

- e. **Incubators.** Incubators may be useful components of a biology laboratory. 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 may be useful in the biology laboratory, especially in biotechnology experiments where agar must be heated to pour gels. Microwave ovens should be safely located and appropriately maintained. Students should be instructed on their proper use. Students with pacemakers should not work in the proximity of a microwave oven.

5. Microscope Work

- a. Microscopes
 - Students should be instructed in the proper use of the microscope.
 - All precautions in dealing with electrical equipment should be followed.
 - If microscopes with reflecting mirrors are used for illumination, care must be taken to prevent using direct sunlight as the illumination source.
 - Students with eye infections should not be allowed to contaminate the eyepiece(s) of the microscope.

- b. Microtomes

A microtome may be a useful tool, especially in upper-level biology classes. Students must be instructed in the proper use of the microtomes, which contain extremely sharp knife blades.

►See Chapter XI.B, Electrical Hazards.

6. Refrigerators and Freezers

►See Chapter VI.E, Refrigerators and Freezers.

C. Microbiology

This section pertains primarily to the use of viruses, bacteria, and other microscopic organisms. Bloodborne pathogens require special considerations. 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 IX.D, Zoology: Animal Considerations, and 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.

(1) A list of sources is available in the National Science Teachers Association annual publication, *NSTA Science Education Suppliers*.



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(2) Other sources may include local research facilities, e.g., universities or hospitals. The American Type Culture Collection, a nonprofit organization, maintains an extensive collection of microbiological specimens that may be purchased. This source is especially useful for obtaining materials not available through other suppliers.



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(3) Specimens should be requested for shipment when needed and not stored for long periods of time.

- c. All microorganisms should be handled as if they were pathogens.
- d. Proper aseptic techniques should be used at all times when working with bacterial, viral, or microbial cultures.
- e. Microorganisms cultured directly from the environment should not be incubated for cell cultures as incubation could promote the growth of pathogenic organisms.

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



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g. Blood agar, serum agar, and/or chocolate agar should be avoided for use in classroom experimentation.

h. Staining reagents may be purchased through supply companies.

►See Chapter IX.B.2.a, Stains, and IX.F.2, Staining DNA.

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 work space 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, dishes and culture plates, etc. is recommended. If you use nondisposable glassware, take care to properly decontaminate it.

►See Chapter VI.A, Glassware.

- g. Special trash containers for all cultures for proper sterilization and disposal
There should be separate containers for disposal of glass, plastic, paper, etc. All trash receptacles should be clearly identified.
 - h. Petri dishes for use with noninfectious materials
 - (1) 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.
 - (2) 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 Chapter IX.C.4, Decontamination and Disposal of Materials.

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
 - (1) Inoculating loops should be flamed before and after the transfer of microorganisms and a final time before storing.
 - (2) The inoculating loop should be used with a steady hand and should not be used for stirring, as splashing may occur.
 - (3) 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 25° C to decrease the possible growth of pathogens.

i. Pipetting of bacteria

- (1) Use a micropipet or disposable pipet and a pipette or pipet bulb. Micropipettes are preferred for transfers of small amounts of liquid inoculant. A disposable pipet is preferred for larger amounts.
- (2) 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.*
- (3) Colonies should be counted on closed Petri dishes or plates. Parafilm is recommended for sealing culture plates.
- (4) Any demonstration plates passed around the class must be sealed with parafilm or tape.
- (5) An autoclave, heat sterilizer, or pressure cooker should be available.

►See Chapter IX.B.4.a, Heating and Sterilization Devices – Autoclaves/Dry Heat Sterilizers/Pressure Cookers. See also Chapter VI.G, Pipets, and Chapter VI.I, Centrifuges.

4. Decontamination and Disposal of Materials

Disposal of scientific materials such as reagents 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 chemical reagents, 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 VII.C.3, Disposing of Waste.

- 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.

- (1) 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.*
- (2) 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.
 - (a) 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.
 - (b) 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 the 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, wastes 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 VI.M, Sharps.

- (c) 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.
- (d) 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. Obviously, 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, epileptics, 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 ear pieces after each use. Teach students the proper use of the stethoscope to avoid potential ear damage.
- d. **Body Fluids and Bloodborne Pathogens**

(1) **Recommendations.** Federal Regulation 29CFR 1910.1030 must be followed. The National Association of Biology Teachers (NABT) makes the following recommendations regarding the use of human body samples in the biology classroom or laboratory:

- (a) Use safer alternatives to human samples when possible. Materials that mimic the properties of blood, saliva, and urine may be purchased. The *American Biology Teacher* journal is a source of information on alternatives.
- (b) Use samples known to be free of disease. Do not use any samples of unknown origin. Avoid samples that are not collected at school.
- (c) Use samples only if all persons in contact with the samples comply with all applicable Universal Precautions. Additional guidelines are available from clinical libraries, hospitals, and public health agencies.
- (d) In addition to the Universal Precautions, teachers using human body samples should conform to the following precautions:



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- Students must be allowed to collect samples only with the supervision and advice of the teacher.
- Samples must be handled with plastic or latex gloves, chemical splash safety goggles, and a laboratory coat or apron.
- Students must always wash their hands after any laboratory activity involving human body samples.

(2) **Basic Precautions.** Below is a list of body fluids and wastes and their possible uses in a high school classroom or laboratory. Teachers must follow school system policy regarding parental permission and students' rights to refuse to participate in experiments using body fluids. Teachers are encouraged to use safer alternatives in place of human samples when possible.

Some of the materials on the list have been identified by the Centers for Disease Control (CDC) as requiring the application of the Universal Precautions. All body fluids and wastes warrant the application of the Universal Precautions. Recommended precautions and procedures:



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- Treat all body fluids and wastes as infectious because it is not possible in the high school laboratory to distinguish that which is and is not infectious.
- Taking body fluids or wastes for experiments must be on a voluntary basis.
- Use sterile techniques to prevent spreading infectious diseases.

► See Chapter IX.C.4, Decontamination and Disposal of Materials.

- (a) **Blood** may be used for blood typing studies and microscopic and biological physiological analysis. Students should be encouraged to obtain their blood type from a doctor and to know their blood type in case of an emergency.
- (b) **Cheek Cells** may be used for microscopic analysis and cell comparison studies.
- (c) **Feces** are rarely used in biology instruction but materials containing feces are sometimes used in microbiology and parasitology studies.
- (d) **Respiratory Mucus** may be used in studies of the respiratory system.
- (e) **Saliva** enzymes may be used in general biology class activities. Cells collected from saliva are used for microscopic analysis and for obtaining (culturing) oral microorganisms from tooth tarter.
- (f) **Semen** samples may be used for microscopic analysis.
- (g) **Urine** may be used for urinalysis or cell culture, which requires the collection of fresh urine.

2. Nonhuman

The Maryland Science Safety Project Committee endorses the National Science Teachers Association's Guidelines for Responsible Use of Animals in the Classroom and the Institute of Laboratory Animal Resources' principles regarding the humane study of animals in precollege education. In all cases, teachers should consult such organizations and agencies as the local Humane Society and the State Department of Natural Resources before bringing animals into the classroom.

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.

- (1) 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: 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 refrigerating culture jars and placing "chilled" flies on a Petri dish over ice.
- (2) Anesthetizing kits also may be used. For example, FlyNap® kits containing relatively 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)

- (1) **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.
- (2) Obtain animals from a certified disease-free source.
- (3) When studying developing chicken embryos, do not use any embryos that are more than 18 days old.
- (4) Do not work with virus-infected eggs.
- (5) Dispose of dead embryos, which may carry pathogenic bacteria.

►See Chapter IX.C.4, Decontamination and Disposal of Materials.



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- (6) Do not give away or sell any animals, including baby chicks.
- (7) Do not release animals that are not indigenous to the area into the environment. Release of indigenous animals must be approved by the State Department of Natural Resources.
- (8) Maryland State Law 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.

Annotated Code of Maryland – Commercial Law, § 11-904. Sale and Coloring of Chicks.

- c. **Other Guidelines for Working with Animals.** The Maryland Science Safety Project Committee supports the following additional guidelines for working with animals in ways that protect students and the animals. Most of these guidelines relate to animals in the classroom.
 - (1) Take care to avoid contact between humans and animals when either of them may be a disease carrier.
 - (2) Keep laboratory animals isolated from wild animals.
 - (3) Only the student assigned responsibility for animal care should have direct contact with the animals.
 - (4) 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 wastes.
 - (5) Protect animals during times of pesticide use.
 - (6) Sterilize cages and equipment before and after use. Use household bleach, 2% phenol, or Lysol®. Rinse cage well with water.
 - (7) Parental permission must be obtained before allowing a student to take an animal home.
 - (8) 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

- (9) 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
 - parakeets and parrots (possible psittacosis infection)
- (10) 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.** By their consistent attitude in working with animals, teachers can encourage students' understanding of the educational value of dissection while being sensitive to living things.
- (1) Living specimens should be maintained in the laboratory until used.
 - (2) 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.
 - (3) Specimens such as frogs can be held for several weeks in the refrigerator.
 - (4) Preserved specimens purchased through reputable biological supply companies are acceptable subjects.
 - (5) Animals killed on highways and other non-preserved specimens should not be used.
 - (6) Certain specimens, such as fish and squid, may be purchased from the frozen foods section of a local grocery store.
 - (7) Teachers should assess their needs carefully and order only enough material for a year. Specimens should not be stored from year to year since deterioration may occur.
 - (8) Before use, specimens should be kept in their original containers and placed in an area not available to students. Decayed preserved specimens should be discarded properly.
 - See Chapter IX.C.4, Microbiology– Decontamination and Disposal of Materials.
 - (9) Preserved specimens should be thoroughly rinsed in running water before use.
 - (10) Freeze-dried specimens that have been rehydrated in a dilute 10% alcohol-water solution for 24 hours should be thoroughly rinsed before use.

- (11) 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 “bioperm.” Specimens retained for further work on succeeding days should be labeled and refrigerated if possible.
- (12) Animal skins can be protected from insect damage by storing them in borax or mothballs.
- (13) While performing dissections, students should wear chemical splash safety goggles. Gloves and aprons should be available for student use.
- (14) Students should wash their hands after any dissection activity.
- (15) All equipment used in dissections should be thoroughly cleaned after each laboratory session.
- (16) Students should be given adequate time to clean tools, pans, and dissecting stations before the end of the laboratory session.
- (17) If the dissection is to be continued at a later time, specimens should be placed in plastic bags to prevent dessication and deterioration. Bags should be clear or clearly labeled.
- (18) Specimens should be bagged and then discarded in an appropriate manner.
 - See Chapter IX.C.4, Microbiology – Decontamination and Disposal of Materials.
- (19) Chemical preservatives should be discarded according to the disposal instructions in the MSDS 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 VII.C.3, Chemical Waste Strategies–Disposing of Waste.

e. Research Procedures

- (1) Use invertebrates for research when appropriate because of their variety and the large number of specimens.
- (2) Vertebrates are appropriate in cases where their similarities to humans are important to the research. Research should be carried out with qualified adult supervision and the advice of a veterinarian.
- (3) Plants should be used wherever possible for experiments on organisms.
 - See Chapter IX.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 IX.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 biology 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: 1-800-492-2414.*
- 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.



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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 IV.A, Eye Protection Concerns.

- 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 above Chapter IX.D.1.d, Zoology: Animal Considerations–Body Fluids and Bloodborne Pathogens.

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 biology 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.



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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 DNA Molecules* dated June 24, 1994 as amended through April 30, 1998. Essential guidelines for handling any microorganism or DNA molecule in the laboratory are also contained in the “Standard Microbiological Practice” 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). The manual, published by the U.S. Department of Health and Human Services, is available online from NIH and CDC.



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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 little 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 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 IX.C.4, Microbiology—Decontamination and Disposal of Materials. Guidance may also be available from a university or research laboratory.
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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.
 - (1) Students should wear latex gloves in handling this stain because it is moderately toxic and will stain skin.
 - (2) 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

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 XI.F.3, Radioisotopes.



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G. Greenhouse Maintenance and Operation

For schools that have greenhouses available for biology and environmental 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 special 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 Chapter IX.G.2, Greenhouse Maintenance and Operation – 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

- (1) Use the least toxic pesticides.

Note signal words found on pesticide labels:

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

- (2) The safest insecticides contain pyrethrins.

b. Using Pesticides

- (1) Pesticides are toxic and should be used only according to instructions on container labels.
- (2) Pesticides can enter the body through the skin, mouth or nose. Before using pesticides, cover up exposed skin with water-repellent clothes and boots.
- (3) Wear a wide-brimmed hat and a full-face shield.
- (4) Use unlined, natural rubber gauntlet gloves.
- (5) Use exhaust hoods and ventilation systems when spraying.
- (6) Do not touch the mouth or face with hands, forearms or clothing.
- (7) Do not expose a drink or food container to pesticides.
- (8) Wash hands and face immediately after applying pesticides.

X. Earth Science

Avoiding Mechanical, Electrical, and Other Hazards

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 III through VII and XI. Because Earth/space science relies on remote sensing for observations and data collections, teachers must also be knowledgeable about the hazards inherent in the instruments used for these procedures.

A. Mechanical Hazards in Earth 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 mainly to illustrate laws of motion.
 - See Chapter IV.A, Eye Protection Concerns.
3. **Sling Psychrometer** – Care should be exercised in using this device. Be sure thermometers are securely fastened.
4. **Rocketry** – Take special care when launching a rocket.
 - See Chapter XI.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.
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.
7. **Wind Generating Devices** (Hair Blower, Electric Fan, etc.) – Take special 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

EARTH/SPACE SCIENCE ACTIVITIES ARE SAFE WHEN . . .

- **activities are selected and planned with student safety in mind.**
- **students are taught the appropriate use of equipment.**
- **protective equipment is available and used as necessary.**
- **care is taken in the selection and use of reagents.**
- **hazards are anticipated and cautions taken to ensure proper functioning of equipment.**

floor. Devices having metal housings should be grounded.

B. Electrical Hazards in Earth Science

Certain devices used in earth science present electrical hazards. These include batteries, power and extension cords, and various electrical equipment.

► See Chapter XI.B, Electrical Hazards.

C. Light Hazards

1. Magnesium Ribbon

Students should not look directly at the flame when a magnesium ribbon is being burned. The extreme brightness can damage the eyes.

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 Kodak publication AM-10, *Solar-Eclipse Photography for the Amateur*.



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.

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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 XI.F.4, Radiation Hazards–Ultraviolet Radiation.

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 VIII, Outdoor Safety – Field Studies.

XI. Physics

Balancing Creativity and Safety

Experimental physics motivates teachers and students to create new techniques and apparatus and to use them to demonstrate both old and new ideas. It is impossible, therefore, to anticipate all of the specific hazards that might arise in the study of physics. 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 high school physics classroom.

A. Mechanical Hazards

1. 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)



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2. 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.

3. 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 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.

PHYSICS LABORATORIES ARE SAFE WHEN . . .

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- activities are selected and planned with student safety in mind.
- hazards are anticipated and cautions taken to ensure proper functioning of equipment.
- students are instructed in the appropriate use of equipment.
- protective equipment is available and used as necessary.

4. 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 object and the magnet. In addition, exposed terminals on electromagnets should be insulated to prevent electric shock hazards.

5. 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 industrial arts instructor should be consulted for proper safety precautions necessary for each tool or machine.

6. 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 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.

7. 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.

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 (Ω)	I (mA)
one dry finger on each electrode	100,000	1.1
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:

$$I = 110 \text{ Volts} = 0.11 \text{ A or } 110 \text{ mA}$$

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 very high 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 very 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 long 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 10^5 volts) with very 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 long 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.
 - See Chapter XI.B.2.c, Circuit Loads.
- 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.
- 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.

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 firmly 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.

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 a protective housing. Under these conditions, safety goggles or shields should be worn by all observers.

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).



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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. 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 essentially 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. Any gas cylinder should be anchored to the wall or mounted in a well-designed holder. 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. Large tanks



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should be carefully moved in a wheeled cart with a tie-down chain safety cap in place, and should never be pulled by the threaded cap or rolled on the floor. (OSHA Regulations: 29 CFR 1910.101).

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 XI.A.6, Mechanical Hazards—Projectiles.
- 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 physics 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. Below are guidelines for heating and handling hot objects.
 - (1) Any glass apparatus that is to be heated should be made of Pyrex® brand or Kimax® brand. It must be free of chips and cracks.
 - (2) Gas burners should be kept away from the body at all times. The pressure of the gas should be adjusted to allow proper ignition. Too high a pressure tends to blow the flame out. Do not allow gas to accumulate if ignition is delayed for any reason.
 - (3) Never heat a closed container if there is no means of pressure relief.
 - (4) 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.
 - (5) Never set hot glassware on cold surfaces or in any other way change its temperature suddenly, because uneven contraction may cause breakage.
- See Chapter VI, 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.
 - (1) Produce steam only in a container with a direct open line to the atmosphere.
 - (2) Instruct students that steam has a very 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.
 - (3) 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 and spillage of mercury. Following the guidelines below will minimize the hazards.
 - (1) Use alcohol thermometers in place of mercury thermometers to eliminate the hazards associated with mercury spills.
 - (2) Consider the range of temperatures to be measured when choosing a thermometer. If heated beyond its capacity, a thermometer may break.
 - (3) 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.
 - (4) If a mercury thermometer is used, be alert to the potentially serious hazard of a mercury spill. Instruct students that they must report any such breakage immediately and remove any source of heat which is present. Each laboratory where mercury is used should be equipped with a mercury-spill kit. Follow the directions that come with the kits.

► See Chapter VI.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

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 as 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.”

- a. Flush the skin that came into contact with the dry ice with water. Water should always be readily available during cryogenic experiments.
- b. 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.
- c. When dry ice is used in a confined space, provide sufficient ventilation to eliminate the risk of asphyxiation. This risk is caused when the more dense carbon dioxide gas released produces an oxygen-deficient layer.
- d. Used to produce a special effect (such as fog in a drama production), dry ice may produce large amounts of carbon dioxide. Students and other teachers should be warned of this risk and informed about avoiding it.
- e. 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 in Physics

1. 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 more dense than air, easily collects in a non-ventilated area.

► See Chapter XI.D.2, Cryogenics.

2. 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.

3. 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.

4. 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 VII.A.4.b, Storage of Flammable and Combustible Liquids, and Chapter VII.B, Handling Reagent Chemicals.

5. Mercury

Do not use mercury in the classroom. Use alternate equipment not requiring mercury in place of mercury. There are many reasons for this recommendation: The vapors from free mercury are cumulatively toxic. Mercury is absorbed through the skin. The vapors it forms are absorbed by inhalation. Complete clean up of any mercury spill, which is absolutely necessary, is difficult to accomplish. *NOTE:* As stated earlier, each laboratory where mercury is used should be equipped with a mercury-spill kit. Follow the directions that come with these commercially available kits.

6. 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 a very small hole onto a white piece of paper about one-half meter behind the hole.

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**

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 **S** especially sealed sources **S** will create minimum hazard because of the small amount of radiation present. 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 radiations 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 physics 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 XI.F.1., Infrared Radiation.
- e. Incandescent ultraviolet lamps present a minimal danger from their ultraviolet emissions, as the energy of this radiation is very 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 Chapter XI.G, Laser Safety.

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 high enough energies.) To minimize possible X-ray exposure, three rules should be observed by teachers and students:

- 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. Commercial companies listed in the yellow pages should be able to provide this service.

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 very short 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 possible 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 III lasers (see chart below), certain safety precautions are important to teach and use when working with lasers.

► See Chapter XI.G.3, Laser Guidelines.

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 almost 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 **S** 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. Each laser is placed into one of at least four separate classes, or risk categories. 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.

LASER RISK CLASSES*

Class	Power Output (mW)	Hazard	Comments
I	<0.39	inherently safe	<i>Exempt lasers.</i> Considered incapable of producing damaging radiation and therefore exempt from control measures. Do not exceed maximum exposure levels.
II	<1.0	low risk	<i>Low-power lasers.</i> Hazardous if looked at continuously. May be viewed directly; avoid continuous intrabeam viewing. Emission limited to 1 mW for less than 0.25 seconds between 400 and 700 nm; hazards are prevented by aversion reflexes.
IIIa	<5.0	low risk	Limit up to five times that for Class II. Viewing by the unaided eye is safe, but the use of optical instruments may be hazardous. Requires control measures that prevent viewing of the direct beam.
IIIb	<500	medium risk	<i>Higher emission limit.</i> Direct viewing may be hazardous; but viewing by diffuse reflection is safe. Requires control measures that prevent viewing of the direct beam.
IV	>500	high risk	<i>High powered systems.</i> Emission limit higher still; even viewing by diffuse reflection may be hazardous. Skin injuries and fire hazard are also possible. Requires the use of controls that prevent exposure of the eye and skin to the direct and diffusely reflected beam.

* Adapted from *Fundamentals of Laboratory Safety*

3. Laser Guidelines

Lasers can be used safely through the use of suitable facilities, equipment, and well-trained personnel. Class II 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 III systems. Eyewear may be necessary if intrabeam viewing cannot be precluded. Operation within a marked, controlled area is also recommended. Finally, for Class IV lasers or laser systems, eye protectors are almost always required; facility interlocks and further safeguards provide additional protection.

The following general guidelines for safe laser use in the classroom are excerpted from *Laser Fundamentals and Experiments*.

- 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 firmly 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.

►See NFPA 1122.



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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 persons 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 ozs.) at liftoff, and the engine must contain no more than 113 grams (4 ozs.) of propellant.

For further information about model rockets and model rocket safety, contact:

Estes Rocket Industries
P.O. Box 227
Penrose, CO 81240

XII. Safety in Elementary School Science

Keys to Safety: Planning, Management, and Monitoring

This chapter provides information to assist the elementary school teacher 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 – a guide to these safe practices – 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, possible hazards, and proper use and disposal of all materials used in the classroom. This information is available through Materials Safety Data Sheets (MSDSs). Federal law requires that vendors of laboratory chemicals provide an MSDS 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 MSDSs be available at the worksite.

► See Appendix C, MSDS: Explanation and Samples.

Science activities are diverse and often more difficult to supervise than other instructional activities. 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.

SCIENCE SAFETY MANUAL CHAPTER SYNOSES: CHAPTERS I - XI

Chapter I: Responsibilities. Safe laboratory program 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. 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, thus ensuring that parents too know and support

TEACHERS ARE RESPONSIBLE FOR . . .

- **exercising good judgment in planning and conducting safe laboratory investigations.**
- **providing students instruction in safe laboratory procedures.**
- **providing supervision for all science activities.**
- **maintaining a written record of student safety instruction.**

the goal of safety in the science classroom.

Chapter II: Legal Aspects of Laboratory Safety. In the event of a charge of negligence in the science laboratory, several parties are potentially liable: the state, the school district, the school board, the school administration, and the teacher. This chapter presents information on the responsibilities the teacher has as the person immediately in charge of pupils in a science activity. Among persons potentially liable, the classroom teacher is most often considered to be placed in the accountable position. Legal action against a teacher stems from the presumption that he or she is the expert in the laboratory and, as such, has the responsibility to ensure that activities are carried out in a prudent and safe manner. The descriptions of and cautions concerning negligent acts are clearly outlined.

ELEMENTS OF LEGAL NEGLIGENCE

- a legal duty of one person to another, as teacher to student
- a breach of this duty
- personal injury or monetary damage caused by the breach of duty
- legal breach judged to be proximate cause of injury or damage

Chapter III: Safety Concerns and Emergency Lab Equipment. Classroom size is a major concern when conducting science activities. There must be a reasonable amount of space for each student and for emergency equipment and storage facilities. Proper maintenance of emergency equipment is essential. Teachers need to know the location and proper use of equipment such as gas and electric cut-offs, fire extinguishers, fire blankets, and eyewash fountains or devices. Materials, storage space, and evacuation routes must be clearly marked. The use of safety goggles is required for many laboratory exercises.

SAFE SCHOOL LABORATORIES HAVE . . .

- adequate work space for students and teachers.
- clearly marked emergency evacuation routes.
- master gas and electric cutoffs.
- properly maintained safety equipment.
- signs and labels to identify safety

A safety plan and first aid kit should be in every classroom. Emergency procedures and phone numbers must be readily available. 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 laboratory activities.

Chapter IV: Personal Safety Provisions. Providing a safe laboratory environment involves a combination of many efforts. Chapter IV provides the information a teacher needs to know about room size, facilities, fire safety, equipment, and proper ventilation. In addition to proper training, procedures, ventilation and emergency equipment, it is important to provide the student with information about personal protection. This information should include the type of clothing

SAFETY IN THE SCHOOL LABORATORY REQUIRES . . .

- the availability and, when necessary, the wearing of aprons and gloves.
- care in preventing clothing or long hair from becoming a hazard.
- special attention to prevent eye damage by wearing appropriate goggles.

worn, length of hair and jewelry and proper use of items such as aprons, goggles and gloves.

Chapter V: Safety Strategies in the Classroom.

Safety considerations are essential when dealing with students and science activities. This chapter provides information on general and specific safety issues related to science activities. In planning and setting up student activities, it is essential to consider safety issues. 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. Students should be taught safe practices. A teacher's supervision of students requires a constant alertness to various types of accidents that might occur and the exercise of common sense.

TEACHERS MAKE LABORATORIES SAFE BY . . .

- teaching students how to conduct investigations 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.

Chapter VI: Safe Handling of Equipment. The safe handling and use of materials and equipment should be foremost in the minds of teachers. This chapter provides guidelines for the safe handling and use of a variety of equipment encountered in an educational setting. 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.

TEACHERS AND STUDENTS AVOID ACCIDENTS

BY...

- using the proper equipment.
- making sure the equipment is clean and in good working order.
- receiving instruction in the proper use of all equipment.
- practicing proper use of equipment.

Chapter VII: Chemicals: Managing, Handling and Disposing.

Ordering, storing, and disposing of reagent chemicals are important procedures that, when properly handled, contribute to a safe science laboratory.

Therefore, all teachers of science need to understand these procedures. Chapter VII presents information about how to order and handle chemicals in ways that help to maintain a safe science classroom. Chemical safety begins with the teacher who orders and uses these products. A teacher considering ordering a chemical for classroom use must understand

MAINTAINING CHEMICAL SAFETY REQUIRES...

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

the relative hazard level of the chemical, 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.

VIII. Outdoor Safety - Field Studies. 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 of the scope of the study and the environment in which it is to be conducted. Teachers help ensure safe field activities also when they maintain up-to-date medical information and emergency phone numbers for all participants.

FIELD STUDIES ARE VALUABLE EDUCATIONAL EXPERIENCES WHEN TEACHERS ...

- keep student safety in mind.
- establish and enforce rules for safe student conduct.
- plan field studies by visiting the site, establishing emergency procedures, and obtaining parental permission.
- ensure that specimen collections are legal and serve valid educational purposes.

IX. Biology and Environmental Science. Some elementary science activities are related to biology and environmental science. There are potential hazards in these areas. Chapter IX contains information on hazards associated with the handling of micro-organisms and animals, classroom activities on the school grounds or outdoor study areas, and containment of biological specimens. The chapter also has information on personal protection devices, classroom safety, microbiology, zoology, botany, biotechnology and greenhouse maintenance and operation. Recognition of potential hazards and development of procedures to avoid or control these hazards are essential

BIOLOGY LABORATORIES ARE SAFE WHEN ...

- student safety is considered in determining an activity's value.
- proper laboratory techniques are taught and practiced.
- physiological measurements are neither stressful nor invasive.
- care is taken in selecting and using reagents.
- specimens are handled according to professional guidelines.

for the completion of safe science activities.

X. Earth Science. Earth/space science offers many possibilities for rewarding elementary school science activities. The activities often involve concepts from chemistry and physics. Chapter X presents information about potential *mechanical* hazards (including rockets, wind generating and force measuring devices), *electrical*,

EARTH/SPACE SCIENCE ACTIVITIES ARE SAFE WHEN ...

- activities are selected and planned with student safety in mind.
- students are taught the safe use of equipment
- protective equipment is available and used as necessary.
- care is taken in the selection and use of reagents.
- hazards are anticipated and cautions taken to ensure proper functioning of equipment.

hazards, *chemical* hazards (including a list and description of specific chemicals), *light* (from the sun, lamps and generated by chemical reactions), and *heat* (gas burners, hot plates and candles).

XI. Physics. Many of the hands-on activities in the elementary science classroom deal with the science of physics. This chapter presents general and specific rules for the safe use of materials and equipment that deal with physics. Topics discussed include hazards associated with mechanical equipment (falling weights, objects in motion), electricity (burns, shocks), vacuums and pressures, heat and cryogenics (hot objects, steam, dry ice), certain chemicals, radiation (lasers, ultraviolet light) and rocketry.

PHYSICS LABORATORIES ARE SAFE WHEN . . .

- activities are selected and planned with student safety in mind.
- hazards are anticipated and cautions taken to ensure proper functioning of equipment.
- students are instructed in the appropriate use of equipment.
- protective equipment is available and used as necessary.

A. General Safety Practices

1. Make safety an integral part of every science activity. In each class preparation, anticipate potential accidents and problems.
2. Review possible hazards and safety concerns with students before each activity.
3. Practice the experiment before presenting it to the class.
4. Keep students on task and allow ample time for cleanup and waste disposal.
5. Do not allow eating or drinking during a laboratory exercise.
6. Encourage students to wash their hands after each science activity.

B. Chemical Safety Hazards

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 possible safety hazards.

1. 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. **Acids.** Acids such as hydrochloric, sulfuric, or nitric acid should not be used. Even "dilute" solutions of these acids can cause skin and eye burns. Two acids generally safe to use are vinegar (weak acetic acid) or a weak citric acid solution. When working with acids, always wear chemical splash safety goggles.

- b. **Asbestos.** Asbestos should not be used and should be discarded according to school system policy. Some forms of this mineral – commonly used in heat-proofing applications – is known to cause cancer.
- c. **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.** Mercury compounds should not be used in the elementary school classroom. Any thermometers or other instruments containing mercury have no place in the elementary classroom and should be properly disposed of. (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 Material Safety Data Sheet (MSDS) provided by chemical supply companies.
► See Appendix C: MSDS: Explanation and Samples.

2. Chemical Safety Practices

Using laboratory chemicals in the elementary science program requires thorough planning by the teacher. The teacher should be familiar with the intended use of the substance, how to handle it safely, and what precautions to use with students.

a. Chemical Labeling

- Label all containers with the substance's common name, precautions, date, and storage area. For each substance, teachers should have available the information listed on the MSDS form.
- Chemicals purchased from major chemical supply companies may have sufficient information on the label (safety warnings and precautions).
- Most elementary "kits" use prepackaged and small amounts of chemicals. These packages may have only the substance name and weight.

- 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 activity, 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.
 - If you use flammable liquids, store them 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 VII.A.4, Chemical Storage.

c. Additional Safety Precautions

- Students should wear chemical splash safety goggles when working with laboratory chemicals.
- Students should be instructed not to taste any laboratory substances and to always wash their hands after use. Provide materials for washing hands at the conclusion of the activity.
- Instruct children not to mix substances at random to satisfy their curiosity.
- Never pipette by mouth. Always use a pipette aspirator bulb.
- Be alert to possible hazards presented by chemicals used in an activity.
- Keep flammable materials (e.g., cooking oil or paper) away from flames.
- Instruct students to smell odors by wafting the odor toward them with a cupped hand.

C. Fire Hazards

1. Fire Types

The potential for fire is ever present in a school. The table below lists the four classes of fires and methods for extinguishing them:

Class	To Fight Fires Involving	Method to Extinguish
A	wood, paper, cloth	Use water or dry chemical extinguisher.
B	gasoline, alcohol, paint, oil, or other flammable liquids	Smother by using carbon dioxide or dry chemical extinguisher.
C	fires in live electrical equipment	Cut off power to electrical equipment. Use multiple purpose (ABC) or carbon dioxide fire extinguisher.
D	metals (Na, K, Mg, etc.)	Scoop dry sand onto fire.

2. Alcohol Burners

Do not use alcohol burners as they are extremely hazardous. Safer alternatives to alcohol burners include candles, hot plates (models without exposed coils), gas burners, or small portable gas cylinders designed for laboratory use.

3. Effective Safety Practices

In case of a classroom fire, the teacher's first response should be to evacuate the classroom. The teacher should know the location and how to use the nearest fire alarm box as well as fire extinguishers, fire blankets, or other fire fighting aids. The teacher should be ready to react to fires on student's clothing or hair. If clothing is on fire, roll the child on the floor to smother the fire. If a fire blanket is quickly available, it should be used. Water, if immediately available, may be used. Do not direct a carbon dioxide (CO₂) fire extinguisher at an individual because such extinguishers produce dry ice that can cause frostbite. Periodically check on the location and condition of fire extinguishers. Students should tie back long, loose hair, and remove bulky coats that could serve as a potential fire hazard.

D. Eye Protection

1. Goggles

Use chemical splash safety goggles when engaged in any activities that might pose a risk of eye injury. Safety goggles should be used when-

- a. using laboratory chemicals in an activity.

- b. using projectiles or sharp objects.
- c. flying particles are likely to be produced (as when solid materials are struck).
- d. when heating materials.

2. Group Demonstrations

For group demonstrations, use a safety shield (clear, impact-resistant plastic) to provide additional safety.

3. Maryland Law

Maryland law requires that teachers, students, and visitors wear approved and appropriate chemical splash safety goggles when caustic or explosive chemicals or hot liquids or solids are in use. (Annotated Code of Maryland. Education Article, 7-4045).



Elementary schools may purchase one set of safety goggles to be kept in the school and shared among all teachers. They would be stored with other science equipment. The goggles should 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 IV.A, Eye Protection Concerns; Chapter VIII.B, At the Site; and Chapter XII.H.4.r, Animal Hazards – Effective Safety Practices.

4. Eye Safety Planning

To ensure an effective program of eye safety, teachers should–

- a. establish a plan for storage, cleaning, and distribution of goggles;
- b. discuss with students the need for and appropriate use of safety goggles;
- c. discuss the need for eye safety when planning science activities;
- d. provide eye protection for everyone performing or observing laboratory activities when there is a risk of a hazard to the eyes.

E. Electrical Hazards

1. Hot Plates

Hot plates are one of the most common electrical devices in the laboratory. Hot plates that have exposed coil wires are not recommended because, when turned on high, the wires become red hot and can ignite a wide variety of combustible materials. Only the solid metal or glass-top hot plates with on/off indicator lights are recommended. Even these types pose risks.

- a. Hot plates should be handled with special care since there is no difference in the appearance of one that is on and one that is off. Even after they have been turned off for several minutes, they remain hot enough to cause a burn.
 - b. Electrical cords can fray and crack with age. This condition can lead to electrical short circuits that can cause burns and/or fires.
 - c. Electrical cords on the floor or draped across desks create tripping hazards.
2. **Batteries**

Batteries (dry cells), especially the alkaline variety, can cause burns to the skin when a wire is placed across both terminals.
 3. **Effective Safety Practices**
 - a. Electrical devices used in the laboratory 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.
 - b. Electrical plugs should not be modified in any way.
 - c. Remind students to remove an electrical plug from a receptacle by pulling the plug, not the cord.
 - d. Children 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.

F. Glassware

1. **Safety Hazards**

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 now are available in plastic. Check with your science supply company.
2. **Effective Safety Practices**
 - a. Always inspect glassware for chips or cracks before and after use. Cracks will eventually work their way through the glass. Discard any cracked item.
 - b. Glassware that is to be heated should be made of borosilicate (e.g., Pyrex®).
 - c. Remember that hot glass and cold glass look exactly the same.
 - d. Never place heated glass items near students.
 - e. Never place heated glass items in water.
 - f. Do not use glassware designed for science experiments as a container for consumable liquids.

G. Field Trips

1. Safety Hazards

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.

2. Safety Practices

►See Chapter VIII, Outdoor Safety –Field Studies.

H. Animal Hazards

The use of live animals in the classroom 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 the humane treatment of animals.



URL 29



URL 46

The humane treatment of animals in research and teaching is a sensitive issue. The Council of State Science Supervisors, the National Association of Biology Teachers, the National Science Teachers Association, the Humane Society of the United States, the Animal Welfare Institute, and the National Society for Medical Research all have established guidelines and position papers supporting the safe and humane treatment of animals used for the cause of science.



URL 60



URL 36

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.



URL 5

2. Animals Not Recommended

Because the following animals present a high risk of infection and/or injury to humans, they should not be kept in the elementary school:

- 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

3. Animals Permitted with Caution

The following animals may be permitted but with the noted caution:

- a. Turtles and snakes: possible salmonella infection
- b. Fur-bearing animals: possible cause of allergies and danger of bites
- c. Tarantulas: biting
- d. Parakeets and parrots: source of psittacosis infection

4. Effective Safety Practices

- 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 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 Maryland law prohibits giving away or selling chicks less than three weeks old.
- q. Do not use any animal that has been preserved in formaldehyde. Formaldehyde is a known human carcinogen. When dealing with preserved animals in the classroom, be alert to the possibility that the animals may be preserved in formaldehyde or other toxic substances.
- r. 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.

►See Chapter IX.D.2.c, Other Guidelines for Working with Animals.

I. Plant Hazards

Plants can be used effectively to provide a living laboratory for elementary school science instruction. By providing experiential learning opportunities, science educators 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.

1. Poisonous Plants

- a. Teachers may want to confine their lesson on poisonous plants (poison ivy, poison oak or poison sumac) to pictures.
- b. 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.
- c. Children should not put any plants in their mouths.

2. Effective Safety Practices

- a. Only plants that are not hazardous to children should be used.
- b. For classroom study, only use plants with which you are familiar.

- c. Treat commercial seeds with care because they may have been treated with toxic fungicides.
- d. Caution children that they should never place any plant or part of a plant in the mouth.
- e. Make hand washing routine procedure after any laboratory activity **S** even when working with plants.

J. Additional Safety Precautions

1. Do not use a thermometer in boiling water unless it is designated for that use.
2. Provide gloves for anyone handling glass wool or steel wool.
3. Do not use reflected sunlight for microscope illumination.
4. Caution children against touching the metal housing of microprojectors as the housing can become extremely hot.
5. 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 IX.C, Microbiology, for proper procedures.
6. When using dry ice, observe these cautions:
 - a. Always handle with gloves or tongs; dry ice can cause burns.
 - b. Do not allow carbon dioxide gas given off by dry ice to accumulate in low areas. The gas is more dense than air and, when it accumulates, can cause asphyxiation.
7. Helium is an inert gas but, if inhaled, replaces oxygen and can cause asphyxiation.
8. Tincture of iodine from the drug store is a satisfactory substitute for iodine crystals for testing for starch.
9. Do not look directly at ultraviolet lamps as the light is dangerous to the eyes and skin.
10. Use alcohol thermometers instead of mercury thermometers. Mercury and mercury compounds are accumulative poisons and should not be used in elementary school.
11. Observe molds in closed containers. Many varieties produce spores that cause allergic reactions or are pathogenic to susceptible individuals.
12. It is important to make the distinction between baking soda and washing soda. Baking soda is sodium hydrogen carbonate (NaHCO_3) and is relatively 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.
13. Caustic soda is sodium hydroxide (lye- NaOH) and an extremely strong base. A strong irritant to eyes and skin, it is not recommended for classroom use.

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. A Safety Rules Agreement (SRA) can be an important 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.

A good SRA should include criteria for –

- student preparation for the laboratory,
- following instructions,
- basic precautions and procedures,
- proper handling of equipment and reagents,
- use of personal protective equipment,
- responding to emergencies,
- laboratory housekeeping,
- notification of parents, 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 or 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 sample SRA's provided in Appendix A are designed for use in a typical high school laboratory environment and may require modification for use in elementary or middle schools or in specific courses. School systems may also want to debate the merits of using one SRA across the system or having different forms used by different schools within the system.

Appendix B

The Chemical Hygiene Plan

The Occupational Safety and Health Administration (OSHA) requires all employers to have Chemical Hygiene Plans that address the following topics.

1. Introduction

- a. Purpose of the plan
- b. Applicability of the plan

2. District Organization and Responsibilities (if applicable)

- a. Superintendent
- b. Principal
- c. Science department head
- d. District officers
- e. School employees
- f. Chemical hygiene personnel including the designation of a Chemical Hygiene Officer
- g. Students

3. General Principles

- a. Preparation for emergencies
- b. Adherence to rules and procedures
- c. Avoiding exposure to hazardous materials
- d. Risk evaluation including criteria for implementing control measures
- e. Exposure limits
- f. Ventilation
- g. MSDSs

4. Standard Operating Procedures for Safety and Health

- a. General rules for laboratory work
- b. Working alone prohibited
- c. Personal protective devices
- d. Planning for safe work habits
- e. Behavior in the laboratory
- f. Personal hygiene
- g. Housekeeping
- h. Food handling
- i. Glassware
- j. Flammability hazards
- k. Electrical hazards
- l. Compressed gases
- m. Prior approval for new operations/processes/activities

5. Record Keeping

- a. Results of air monitoring
- b. MSDSs
- c. Training records
- d. Exposure testing records
- e. Medical records
- f. Prior approval records
- g. Incident reports
- h. Chemical inventory records
- i. Waste disposal records
- j. Safety inspection results

6. Laboratory Safety Procedures

- a. Employee protection
- b. Facilities
- c. Ventilation
- d. Medical consultation/examination including the following requirements:
 - (1) Whenever exposure occurs the employee must be given the opportunity for medical consultation to determine the need for a medical examination at no cost to the employee.
 - (2) Obtain a written opinion from the physician for all medical consultations.
- e. Reagent purchasing
- f. Chemical storage
- g. Inventory control
- h. Labeling
- i. MSDSs
- j. Waste disposal

7. Inspections

- a. Laboratory equipment including ventilation hood performance evaluations
- b. Safety audits

8. Exposure Control Including Monitoring

- a. Toxins
- b. Flammables
- c. Reactives
- d. Corrosives
- e. Reproductive toxins
- f. Carcinogens including the handling of "select carcinogens" to provide for:
 - (1) establishing designated areas
 - (2) determining containment devices
 - (3) establishing methods of disposal
 - (4) instituting methods of decontamination
- g. Exposure potential

9. Employee Information and Training

- a. The existence and content of the OSHA Laboratory Standard
- b. The location and availability of the Chemical Hygiene Plan
- c. Occupational exposure standards, such as OSHA Permissible Exposure Limits
- d. Signs and symptoms associated with the overexposure to chemicals
- e. The location of reference materials such as MSDSs
- f. The methods and observations that employees may use to detect the presence or release of hazardous chemicals
- g. Work practices, emergency response procedures, and protective equipment to be used
- h. Training of students

10. Emergency Procedures

- a. Response procedures including an evacuation plan
- b. First aid
- c. Emergency equipment
- d. Fire prevention
- e. Fire fighting
- f. Injuries involving fire
- g. Chemical spills on personnel
- h. Eye splashes
- i. Medical help
- j. Injury to personnel
- k. Chemical spills
- l. Accident reports

11. Spill response

- a. Personal injury
- b. Identification of the spilled material
- c. Containment of the spilled material
- d. Cleanup of the spilled material
- e. Protective equipment
- f. Training for emergencies
- g. Disposal of cleanup materials
- h. Record keeping

In addition, appendices should be attached to the plan, including a copy of the OSHA Laboratory Standard, a bibliography, various forms to be used, and any other information specific to the local operation.

In developing plans, Chemical Hygiene Officers are encouraged to use the American Chemical Society publication, *A Model Chemical Hygiene Plan for High Schools*, and the model plan designed by the Flinn Scientific Company. Additional suggestions can be found in 29CFR1910.1450, Appendix A.

Appendix C

Material Safety Data Sheets (MSDS): Explanation and Samples

EXPLANATION

The Hazard Communication Standard (29CFR1910.1200), also known as the Right-to-Know Law, requires the maintenance of Material Safety Data Sheets (MSDS) for every hazardous material located at the school (29CFR1910.1200(g)).

Manufacturers or distributors of hazardous materials are required to supply you with an MSDS when you purchase hazardous materials from the manufacturer or distributor. No standard form is required, but most manufacturers use either the American National Standards Institute (ANSI) form or the Occupational Safety and Health (OSHA) form. Both are described below. You may find after an inventory that you have in storage some materials for which no MSDS has been supplied. In that case, you should write your own using one of the forms described or download one from the Internet sources listed in Appendix H.



URL 6

Other sections of the Hazard Communication Act (available on the Internet at the access.gpo site) that may be of interest include:

- (c) Definitions - very valuable!
- (d) Hazard determination
- (e) Written hazard communication program
- (f) Labels and other forms of warning

Appendix A to 1910.1200 - Health Hazard Definitions

Appendix B to 1910.1200 - Hazard Determination

Appendix C to 1910.1200 - Information Sources



**URL
66**

ANSI MSDS

Section 1 - Chemical product and Company Identification

The name on the label and any synonyms; the manufacturer or distributor's name, address, emergency telephone number, date MSDS was prepared or revised

Section 2 - Composition, Information on Ingredients

The composition of mixtures; the identity of the hazardous ingredient(s) including both chemical and common name(s); Chemical Abstracts Registry Number (CAS); PEL (permissible exposure limit), TLV (threshold limit values), any other recommended limits

Section 3 - Hazard Identification

Appearance of material; health effects, signs and symptoms of exposure, mode of entry (inhalation, skin, ingestion), target organs

Section 4 - First Aid Measures

Emergency and first aid procedures to be followed after exposure

Section 5 - Fire-Fighting Measures

Extinguishing agents; danger of explosion; special fire fighting procedures; flash point and method of determination; flammable limits, lower explosion limit (LEL), upper explosion limit (UEL);

Section 6 - Accidental Release Measures

How to respond to spills, leaks, air release including containment and type of equipment to be used

Section 7 - Handling and Storage

Precautions to prevent overexposure; instructions for hygiene

Section 8 - Exposure Controls and Personal Protection

Engineering controls (including equipment and ventilation - local or mechanical); personal protective equipment (eye, skin - gloves and clothing, respiratory, including type of device); work and hygiene practices

Section 9 - Physical and Chemical Properties

Appearance, odor, physical state, pH, vapor pressure, vapor density, evaporation rate, boiling point, melting point, solubility in water, density or specific gravity

Section 10 - Stability and Reactivity

Stability; hazardous by-products of decomposition or burning; possible hazardous reactions; conditions to avoid; incompatibilities; possibility of hazardous decomposition or polymerization

Section 11 - Toxicological Information

Data used to identify hazard; acute data; carcinogenicity (National Toxicological Program - NTP, Occupational Safety and Health Administration - OSHA, International Agency for Research on Cancer - IARC); reproductive effects; target organ effects; acute and chronic health hazards; medical conditions aggravated by exposure

Section 12 - Ecological Information

Impact on the environment should release occur

Section 13 - Disposal Considerations

Disposal, recycling, reclamation

Section 14 - Transport Information

Hazard materials description; hazard class, ID number (UN or NA)

Section 15 - Regulatory Information

Information from: Occupational Safety and Health Administration (OSHA); Toxic Substances Control Act (TSCA); Comprehensive Environmental Response, Composition, and Liability Act (CERCLA); Superfund Amendments and Reauthorization Act (SARA)

Section 16 - Other Information

Hazard rating; preparation and revision of MSDS; label information

OSHA

Identity as printed on label

Section I

Same as ANSI form Section 1 (See above)

Section II - Hazard Ingredients/Identity Information

Same as ANSI form Section 2 (See above)

Section III - Physical/Chemical Characteristics

Same as ANSI form Section 9 (See above)

Section IV - Fire and Explosion Hazard Data

Same as ANSI form Section 5 (See above)

Section V - Reactivity Data

Same as ANSI form Section 10 (See above)

Section VI - Health Hazard Data

Same as ANSI form Sections 3,4 and 11 (See above)

Section VII - Precautions for Safe Handling and Use

Same as ANSI form Sections 6, 7, and 13 (See above)

Section VIII - Control Measures

Same as ANSI form Section 8 (See above)

Appendix D

Safety Checklists: Classrooms, Chemical, Electrical, and Refrigerators

✓ ROOM SAFETY INSPECTION CHECKLIST

Room: _____ Inspector: _____ Date: _____

Check for 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			
Table tops 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 STOREROOM

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.			
MSDS 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 chemical 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 (Daniel Woodhead Company, Northbrook,IL) 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.			

✓ SAFETY CHECKLIST FOR REFRIGERATORS AND FREEZERS: FLAMMABLE MATERIALS

Room: _____ Inspector: _____ Date: _____

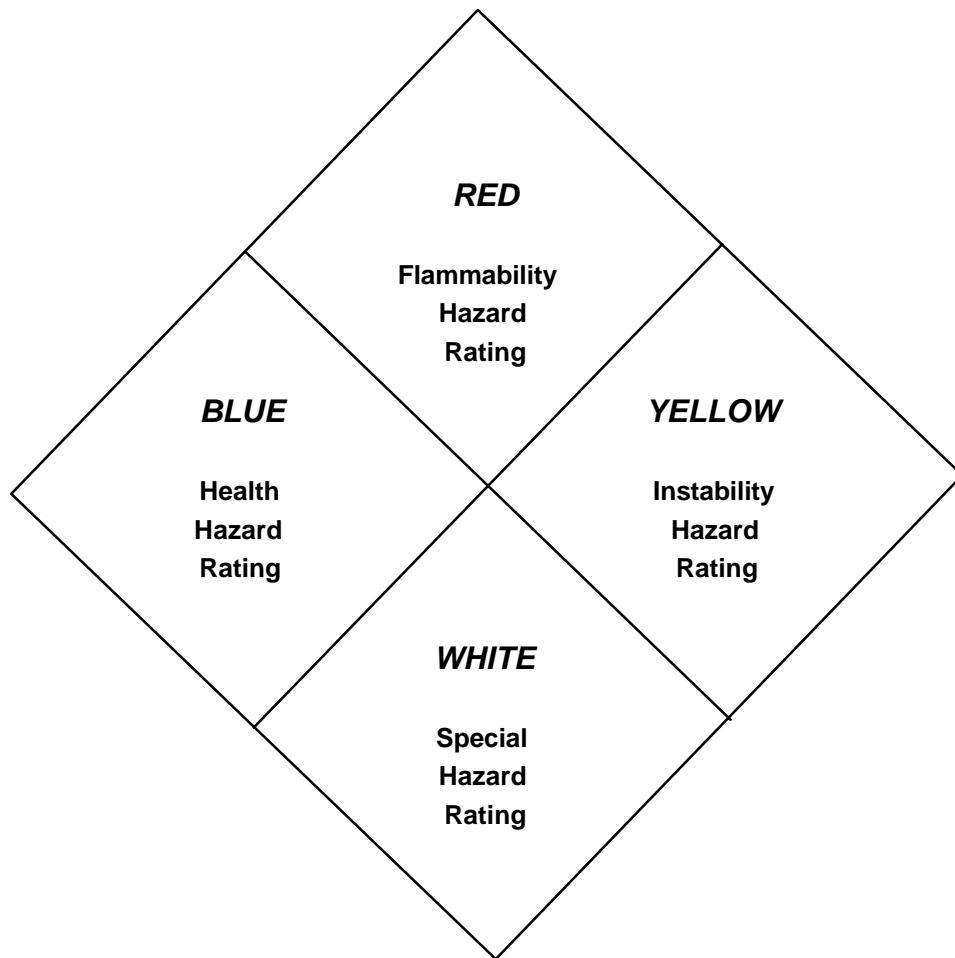
Type of refrigerated appliance: explosion-proof refrigerator
 domestic
 flammable material storage

Special Safety Design Features	Yes	No	Date Remedied
Grounded by 3-wire cord and plug or independent ground wire			
Ground wire in good condition			
Door gasket seal in good condition			
Static-resistant drive belt			
Explosion-proof electrical enclosures, motor housing, conduit properly maintained			

Storage Compartment Safety	Yes	No	Date Remedied
Storage instructions posted on door			
Containers clearly labeled			
Large containers stored on low-level shelves			
Containers safely sealed			
Liquid storage containers have adequate vapor space, allowing for thermal expansion			
Interior wall surfaces clean and free of excessive ice build-up			

Appendix E

National Fire Protection Association (NFPA) Identification Codes



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.

Next page: Flammability, Instability, and Special Hazards

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 in 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 in 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 1500°F (815.5°C) for 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.

Special Hazards

Properties of the material that cause special problems or require special fire-fighting techniques.

Materials that demonstrate unusual reactivity with water shall be identified by the letter **W** with a horizontal line through it.

Materials that possess oxidizing properties shall be identified with the letters **OX**.

- Additional information on the definitions of the hazard ratings can be obtained from NFPA 704, Standard System for the Identification of the Hazards of Materials for Emergency Response.

Appendix F

Storage of Chemicals

It is important to avoid storing incompatible chemicals together. In the list below, do not store chemicals in the left column together with chemicals in the right column.

This chemical is . . .	incompatible with this chemical:
I. acids	bases
A. nitric acid	metals, acetic acid sulfuric acid, sulfides, nitrites and other reducing agents, chromic acid and chromate, permanganates, flammable liquids.
B. oxalic acid	silver, mercury
C. sulfuric acid	metals, chlorates, perchlorates, permanganate, nitric acid
II. alkali and alkaline earth metals and their carbides, hydrides, hydroxides, oxides, peroxides	water, acids, halogenated organics oxidizing agents
III. ammonia	halogens, silver, mercury, sodium hypochlorite (bleach)
IV. carbon, activated	oxidizing agents*
V. hydrogen peroxide	metals and their salts
VI. inorganic azides	acids, heavy metals and their salts, oxidizing agents*
VII. inorganic cyanides	acids, strong bases
VIII. inorganic nitrates	acids, metals, nitrites, sulfur
IX. inorganic nitrites	acids, oxidizing agents*
X. inorganic sulfides	acids
XI. organic compounds	oxidizing agents*
A. acetylene and monosubstituted acetylenes (R-CCH)	halogens, Group 11 and 12 metals and their salts
B. organic acyl halides	bases, organic hydroxy compounds
C. organic anhydrides	bases, organic hydroxy compounds
D. organic halogen compounds	aluminum metal
E. organic nitro compounds	strong bases
XII. phosphorus (yellow)	oxygen, oxidizing agents*, strong bases
XIII. phosphorus pentoxide	water
XIV. powdered metals	acids, oxidizing agents*

* Oxidizing agents include chromates, dichromates, chromium (VI) oxide, halogens, hydrogen peroxide and peroxides, nitric acid, nitrates, perchlorates and chlorates, permanganates, and persulfates.

This table was adapted from *Prudent Practices in the Laboratory*, 1995. Additional information on chemical incompatibility and storage patterns is available in the annual *Chemical and Biological Catalog Reference Manual* published by Flinn Scientific, Inc.

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 autooxidants; that is, they react with the oxygen of the air to form peroxides. Once formed, these peroxides are very 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 MSDS. 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	Isopropyl ether
Acetic acid	Methylacetylene
Acrylonitrile	Methylcyclopentane
Butadiene	Methyl iso-butyl ketone
Chlorobutadiene	Methyl methacrylate
Chlorotrifluoroethylene	Potassium
Cumene	Potassium amide
Cyclohexene	Sodium amide
Cyclooctene	Styrene
Cyclopentene	Tetrafluoroethylene
Diacetylene	Tetrahydrofuran
Dicyclopentadiene	Tetrahydronaphthalene
Diethylene glycol dimethyl ether	Vinyl acetate
Diethyl ether	Vinyl acetylene
Dioxane	Vinyl chloride
Divinyl ether	Vinyl ethers
Divinylacetylene	Vinyl pyridine
Ethylene glycol dimethyl ether	Vinylidene chloride
Furan	

Appendix H

Bibliography for Laboratory Health and Safety

The Most important single reference for schools is the National Research Council's *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*. It was published in Washington, D.C. by the National Academy Press in 1995. Additional information of value to science teachers is provided by a wide variety of publications and Internet web sites of the federal government and state agencies, professional associations, and private publishers. This listing is divided into three sections:

- I. References Providing Information on General Laboratory Safety,
- II. Sources for More Specific Information on Individual Hazards, and
- III. Significant Safety-Related Internet Sites.

In this Manual, references to Internet sites are marked by  this icon: The number under the symbol refers to one of the numbered websites listed in part three of this bibliography. In the electronic version of the Manual available on the Maryland State Department of Education website, the icon serves as a direct link to the appropriate website, which provides more detailed information about the topic discussed in the Manual.

I. References Providing Information on General Laboratory Safety

Occupational Safety and Health Administration (OSHA). *29CFR1910 Occupational Safety and Health Administration*. Washington, D.C.: Government Printing Office, 1999 (annual).*

Environmental Protection Agency (EPA). *40CFR Environmental Protection Agency*. Washington, D.C.: Government Printing Office, 1999 (annual). *

Department of Transportation (DOT). *49CFR Department of Transportation*. Washington, D.C.: Government Printing Office, 1999 (annual). *

Flinn Scientific, Inc. *Chemical and Biological Catalog Reference Manual*. Batavia, IL: Flinn Scientific, Inc., 1999 (annual).

National Fire Prevention Association. *Model Rocketry*, NFPA 1122. Quincy, Massachusetts: National Fire Prevention Association, 1997.

ACS [American Chemical Society] Task Force on Laboratory Waste Management. *Laboratory Waste Management: A Guidebook*. Washington, D.C.: American Chemical Society, 1994.

Committee on Chemical Safety. *Safety in Academic Chemical Laboratories*, 6th ed. Washington, D.C.: American Chemical Society, 1995.

Committee on Chemical Safety. *Safety in the Elementary (K-6) Science Classroom*, American Chemical Society, Washington, DC, 1997

Coté, Ron. *Life Safety Code Handbook*, 7th ed. Quincy, Massachusetts: National Fire Prevention Association, 1997.

DiBerardinis, Louis. *Handbook of Occupational Safety and Health*, 2d ed. New York: John Wiley & Sons, Inc., 1998.

* This item is available on the Internet.

- DiBerardinis, Louis J., et al. *Guidelines for Laboratory Design: Health and Safety Considerations*, 2d ed. New York: John Wiley & Sons, Inc., 1993.
- Earley, Mark W. *National Electrical Code Handbook*, 7th ed. Quincy, Massachusetts: National Fire Prevention Association, 1999.
- Forum for Scientific Excellence. *Concise Manual of Chemical and Environmental Safety in Schools and Colleges* (Volume 1: Basic Principles; Volume 2: Hazardous Chemical Classes; Volume 3, Chemical Interactions; Volume 4, Safe Chemical Storage; Volume 5, Safe Chemical Disposal). Philadelphia, PA: J. B. Lippincott, 1989.
- Forsberg, Krister, and S. Z. Mansdorf. Quick Selection Guide to Chemical Protective Clothing, Third Edition, New York, John Wiley & Sons, Inc., 1997.
- Furr, A. Keith. *CRC Handbook of Laboratory Safety*, 4th ed. Boca Raton, FL: CRC Press, 1995.
- Gatewood, Gari, and Larry Oldendorf. *Research and Development Safety Notebook*, Itasca, IL: National Safety Council, 1976.
- LeFèvre, Marc J., and Shirley Conibear. *First Aid Manual for Chemical Accidents*, New York: John Wiley & Sons, Inc., 1997.
- Mahn, William J. *Fundamentals of Laboratory Safety: Physical Hazards in the Academic Laboratory*. New York: Van Nostrand Reinhold, 1991.
- National Science Teachers Association. *Safety in the Secondary Classroom*. Washington, D.C.: National Science Teachers Association, 1993.
- NIOSH/OSHA. *Pocket Guide to Chemical Hazards*. Washington, D. C.: U.S. Department of Health and Human Services, 1997.
- NIOSH/OSHA. *Occupational Health Guidelines for Chemical Hazards*. Washington, D. C.: U.S. Department of Health and Human Services, 1992.
- Pipitone, David L. *Safe Storage of Laboratory Chemicals*, 2d ed. New York: John Wiley & Sons, Inc., 1991.
- Royal Society of Chemistry. *Safe Practices in Chemical Laboratories*. London: Royal Society of Chemistry, 1989.
- Royal Society of Chemistry. *Control of Substances Hazardous to Health in Laboratories*. London, Royal Society of Chemistry, 1996.
- School Facilities Branch. *Science Facilities Design Guidelines*. Baltimore: Maryland State Department of Education, 1994.
- Stricoff, R. Scott, and Douglas B. Walters. *Handbook of Laboratory Health and Safety*, 2d ed. New York: John Wiley & Sons, Inc., 1995.
- Task Force on Chemical Safety. *A Model Chemical Hygiene Plan for High Schools*. Washington, D. C.: American Chemical Society, 1995.
- Wood, Clair. *Safety in School Science Labs*. Natick, MA: James A. Kaufman Associates, 1991.
- Young, Jay A., et al. *Developing a Chemical Hygiene Plan*. Washington, D. C.: American Chemical Society, 1990.

II. Sources for More Specific Information on Individual Hazards

American Society of Safety Engineers. *American National Standard: Practice for Occupational and Educational Eye and Face Protection*, Z87.1-1989 (as corrected 1991). New York: American National Standards Institute, 1989.

Armour, M. A. *Hazardous Laboratory Chemicals Disposal Guide*, Boca Raton, FL: CRC Press, 1996.

Bretherick, L. *Handbook of Reactive Chemical Hazards*, 5th ed. London: ButterworthsHeinemann, 1995.

Budavari, Susan. *The Merck Index*, 12th ed. Whitehouse Station, NJ: Merck & Co., 1996.

Chemical Manufacturers Association. *American National Standard for Hazardous Industrial Chemicals - Precautionary Labeling*, Z129.1-1994. New York: American National Standards Institute, 1989.

Flammable and Combustible Liquids Committee. *Flammable and Combustible Liquids Code*, NFPA 30. Quincy, MA: National Fire Protection Association, 1996.

Horn, Toby M.. *Working with DNA and Bacteria in Precollege Science Classrooms*. Reston, VA: National Association of Biology Teachers, 1993.

Industrial Safety Equipment Association. *American National Standard for Emergency Eyewash and Shower Equipment*, Z358.1-1998. New York: American National Standards Institute, 1989.

Kucera, Thomas J., ed. *Teaching Chemistry to Students with Disabilities*. Washington, D.C.: American Chemical Society, 1993.

Lenga, R. E. *The Sigma-Aldrich Library of Regulatory and Safety Data*. Milwaukee: Sigma-Aldrich Corporation, 1993.

Lewis, Richard J., Sr. *Hazardous Chemicals Desk Reference*, 4th ed. New York: Van Nostrand Reinhold, 1997.

Lewis, Richard J., Sr. *Sax's Dangerous Properties of Industrial Materials*, 9th ed. New York: John Wiley & Sons, Inc., 1998.

Lunn, George, and Eric B. Sansonne. *Destruction of Hazardous Chemicals in the Laboratory*, 2d ed. New York: John Wiley & Sons, Inc., 1994.

Meyer, Eugene. *Chemistry of Hazardous Materials*, 2d ed. Upper Saddle River, NJ: Prentice-Hall Inc., 1997.

National Fire Prevention Association. *Fire Protection Guide to Hazardous Materials*, 12th ed. Quincy, MA: National Fire Protection Association, 1997. [Contains the following four documents: *Hazardous Chemical Data*, NFPA 49, 1994 ed.; *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, NFPA 325, 1994 ed.; *Guide to Hazardous Chemical Reactions*, NFPA 491, 1997 ed.; and *Identification of the Hazards of Materials for Emergency Response*, NFPA 704, 1996 ed.]

National Research Council. *Prudent Practices for the Disposal of Chemicals from Laboratories*. Washington, D.C.: National Academy Press, 1983.

National Safety Council. "Ergonomics Relieves Stress, Fatigue Associated with VDTs." School Safety World Newsletter, Fall, 1982.

NIOSH, *Register of Toxic Effects of Chemical Substances*, Washington, D. C.: Department of Health and Human Services, 1988.

Pohanish, Richard P., and Stanley A. Greene. *Hazardous Materials Handbook*. New York: John Wiley & Sons, Inc., 1996.

Ramsey, Henry, and W. H. Jack Breazale, Jr. "Contact Lenses." *Chemical and Engineering News*, vol. 76, no. 2 (June 1, 1988): 6.*

Stopford, Woodhall, and William Bunn. *Effects of Exposure to Toxic Gases: First Aid and Medical Treatment*. East Rutherford, NJ: Matheson Gas Products, 1988.

Technical Committee on Chemistry Laboratories. *Standard on Fire Protection for Laboratories Using Chemicals*, NFPA 45. Quincy, MA: National Fire Protection Association, 1996.

United States Coast Guard. *Chemical Hazard Response Information System: Hazardous Chemical Data*, Washington, D. C.: Department of Transportation, 1992.

III. Significant Safety-Related Internet Sites

A safety electronic mailing list is provided by ListServe @UVMVM.UVM.EDU.

The following website addresses are preceded by <http://www>. except as noted.

The best place to start is the Division of Chemical Health and Safety (DCHAS) of the American Chemical Society at <http://dchas.cehs.siu.edu>. The DCHAS site contains many hot-links to other pertinent sites.

Ref. #	Web Addresses (http://www +)	Organization or Information Available
1.	access.gpo.gov/nara/cfr/index.html	source for Code of Federal Regulations (CFR)
2.	access.gpo.gov/su_docs	pathogens and prescription drugs
3.	acs.org	American Chemical Society
4.	adsa.uiuc.edu	American Dairy Science Assoc. – care and use of agricultural animals in research, teaching
5.	animalwelfare.com	Animal Welfare Institute
6.	ansi.org	American National Standards Institute
7.	aphis.usda.gov/ac/awainfo.html	U.S. Dept. of Agriculture – Animal Welfare Act
8.	ase.org.uk/policy/classf.html	Assoc. of Science Education – class size
9.	atf.treas.gov	Bureau of Alcohol, Tobacco, and Firearms

Ref. #	Web Addresses (http://www +)	Organization or Information Available
10	atcc.org	American Type Culture Collection – bacteria
11.	bsa.scouting.org	Boy Scouts of America
12.	carolina.com	Carolina Biological Supply – bacterial cultures
13.	ccohs.ca	Canadian Occupational Safety and Health – source for Material Safety Data Sheets (MSDS)
14.	cdc.gov	Center for Disease Control – infectious agents
15.	cdc.gov/od/ohs/biosfty/biosfty.htm	Center for Disease Control – biosafety
16.	cfc-efc.ca/docs/00000138.htm	Canadian Child Care Federation – water safety
17.	chem.uky.edu/resources/msds.html	University of Kentucky – source for Material Safety Data Sheets (MSDS)
18.	chem.unl.edu/safety	University of Nebraska-Lincoln – general high school laboratory safety
19.	clean.rti.org	Research Triangle Institute – waste minimization
20.	cpsc.gov	Consumer Product Safety Commission
21.	cvm.fda.gov	Food and Drug Administration – radiation safety
22.	dehs.umn.edu/links.html	University of Minnesota – links to safety information sources
23.	dllr.state.md.us/labor/mosh.html	Maryland Occupational Safety and Health Admin.
24.	dnr.state.md.us/index.html	Dept. of Natural Resources – animal care
25.	dot.gov	U.S. Department of Transportation
26.	ehis.niehs.nih.gov	National Institutes of Health – Annual Report on Carcinogens
27.	ehs.ucdavis.edu	U. of California-Davis – extensive information on safety
28.	enc.org	Eisenhower National Clearing House
29.	enc.org/csss/index.html	Eisenhower National Clearing House – animals in the classroom
30.	epa.gov	Environmental Protection Agency

Ref. #	Web Addresses (http://www. +)	Organization or Information Available
31.	fda.gov	Food & Drug Admin. – lasers and radiation
32.	fda.gov/cdrh/index.html	Food & Drug Admin. – radiation safety
33.	flinnscli.com	Flinn Scientific
34.	girlscouting.net	Girl Scouts of America
35.	hazmat.dot.gov (not preceded by www.)	U.S. Dept. of Transportation–hazardous materials data
36.	hsus.org/programs/research/animals_education.html	Humane Society of the United States – animal care
37.	kodak.com	Eastman Kodak Co. – publications
38.	labsafety.com	Lab Safety Supply Catalog
39.	labsafety.org	Laboratory Safety Workshop – publications
40.	lawguru.com/search/lawsearch.html	Law Guru – Annotated Code of Maryland
41.	law.indiana.edu/envdec/c.html	Indiana University – Endangered Species Act
42.	law.vill.edu	Villanova University – links to federal sites
43.	lib.uchicago.edu	University of Chicago – safety bibliography
44.	mdk12.org.practices/support_success/specific/science	Maryland State Department of Education – electronic version of Science Safety Manual
45.	msde.state.md.us	Maryland State Department of Education website
46.	nabt.org	National Association of Biology Teachers
47.	nabt.org/journal.html	National Association of Biology Teachers – American Biology Teacher
48.	nap.edu	National Academy Press
49.	nap.edu/readingroom/books/ labrats	National Academy Press – guide to care and use of laboratory animals
50.	www2.nas.edu/ilarhome	National Academy of Sciences – Institute of Laboratory Animal Resources
51.	nfpa.org	National Fire Protection Association
52.	nih.gov/grants/oprr/oprr.htm	National Institutes of Health – human experimentation

Ref. #	Web Addresses (http://www +)	Organization or Information Available
53.	nih.gov/od/orda/toc.htm	National Institutes of Health – NIH Guidelines for Research Involving Recombinant DNA Molecules
54.	nih.gov/od/ors/ds	National Institutes of Health – laboratory safety
55.	nih.gov/od/ors/ds/page2/biosafe.htm	National Institutes of Health – rDNA
56.	nih.gov/od/ors/ds/pubs/bmbl	National Institutes of Health – Biosafety in Microbiological and Biomedical Laboratories
57.	nlm.nih.gov	National Institutes of Health – endangered species
58.	nrc.gov	National Regulatory Commission – isotopes
59.	nsc.org	National Safety Council
60.	nsta.org	National Science Teachers Association
61.	nsta.org/handbook/animals.htm	National Science Teachers Association – Guidelines for Responsible Use of Animals in the Classroom
62.	nsta.org/handbook/workingconditions.htm	National Science Teachers Association – class size
63.	nsta.org/scisupp	National Science Teachers Association – science education suppliers
64.	npt-server.niehs.nih.gov	National Toxicological Program
65.	ohm.volpe.dot.gov	Department of Transportation – hazmat data
66.	osha.gov	Occupational Safety and Health Admin.
67.	pharmacy.ab.umd.edu/~mpc/	Maryland Poison Control Center
68.	pitt.edu	University of Pittsburgh – toxicology data
69.	redcross.org/news/common/96/05%2D96.html	Red Cross – water safety
70.	rpi.edu/dept/chem	Rensselaer Polytechnic Institute
71.	safekid.org	National Safekids Campaign
72.	safetyinfo.com	Safety Engineering – general safety information
73.	safetyonline.net	VerticalNet – sources for safety equipment
74.	science.cc.uwf.edu/nsela/size.htm (not preceded by www.)	National Science Education Leadership Association – class size

Ref. #	Web Addresses (http://www +)	Organization or Information Available
75.	sciserv.org	Science Service – International Science and Engineering Fair
76.	seattle.battelle.org	Battelle Laboratories – waste minimization
77.	siri.uvm.edu/msds (not preceded by www.)	University of Vermont -- good source for Material Data Safety Sheets (MSDS)
78.	sis.nlm.nih.gov	National Institutes of Health – animal welfare
79.	umich.edu	University of Michigan – radiation and health physics
80.	uml.edu	University of Massachusetts – waste minimization
81.	usdoj.gov/dea	Drug Enforcement Agency
82.	wonder.cdc.gov/wonder/prevguid/p0000255/entire.htm (not preceded by www.)	Center for Disease Control – Universal Precautions

Appendix I

Biological Safety: Universal Precautions

The Universal Precautions advocated by the Center for Disease Control (CDC) and the National Institutes of Health (NIH) have grown out of the dangers inherent in the handling of the Human Immunodeficiency Virus (HIV). As more has been learned about the transmission of pathogens from handling infectious materials, the rules have been expanded to cover virtually all infectious materials, not just HIV. The evolution of these rules can be traced through the following CDC documents:

Recommendations for Prevention of HIV Transmission in Health-Care Settings, MMWR 36(SU02);001, 8/21/1987.

Perspectives in Disease Prevention and Health Promotion Update: Universal Precautions for Prevention of Transmission of Human Immunodeficiency Virus, Hepatitis B Virus, and Other Blood borne Pathogens in Health-Care Settings, MMWR 37(24); 377-388, 6/24/1998.

Guidelines for Prevention of Transmission of Human Immunodeficiency Virus and Hepatitis B Virus to Health-Care and Public-Safety Workers, MMWR - Vol. 38, No. S-6, 6/23/1989.

Universal Precautions for the Prevention of Transmission of HIV and Other Bloodborne Infections, Hospital Infections Program (URL:
<http://www.cdc.gov/ncidod/hip/blood/universa.htm>)

These detailed instructions are much more extensive than is normally applicable to elementary and secondary educational institutions. Fortunately, NIH has prepared a very brief summary that will suffice for almost all situations met in elementary and secondary schools. This summary is presented here for your use. The detailed instructions, if needed, are available on-line from the CDC site listed in Appendix H.

Universal Precautions:

1. **Barrier protection** should be used at all times to prevent skin and mucous membrane contamination with blood, body fluids containing visible blood, or other body fluids (cerebrospinal, synovial, pleural, peritoneal, pericardial, and amniotic fluids, semen and vaginal secretions).
Barrier protection should be used with ALL tissues.
The type of barrier protection used should be appropriate for the type of procedures being performed and the type of exposure anticipated. Examples of barrier protection include disposable lab coats, gloves, and eye and face protection.
2. **Gloves** are to be worn when there is potential for hand or skin contact with blood, other potentially infectious materials, or items and surfaces contaminated with these materials.
3. Wear **face protection** (face shield) during procedures that are likely to generate droplets of blood or body fluid to prevent exposure to mucous membranes of the mouth, nose and eyes.
4. Wear **protective body clothing** (disposable laboratory coats (Tyvek)) when there is a potential for splashing of blood or body fluids.
5. **Wash hands of other skin surfaces** thoroughly and immediately if contaminated with blood, body fluids containing visible blood, or other body fluids to which universal precautions apply.
6. **Wash hands immediately** after gloves are removed.
7. **Avoid accidental injuries** that can be caused by needles, scalpel blades, laboratory instruments, etc. when performing procedures, cleaning instruments, handling sharp instruments, and disposing of used needles, pipettes, etc.
8. Used needles, disposable syringes, scalpel blades, pipettes, and other **sharp items are to be placed in puncture resistant containers** marked with a biohazard symbol for disposal.