Safety Guidelines for Chemical Demonstrations

American Chemical Society Division of Chemical Education

Appropriate physical and chemical demonstrations in the classroom or in a public venue have both educational and motivational value and are a long-standing pedagogy in chemical education. Individuals planning chemical demonstrations have a responsibility to follow and document safe laboratory practices for each demonstration. These guidelines have been created based on current best practices and provide a checklist of key issues for demonstrators to assure that chemical demonstrations are conducted safely and without incident. **Because no such set of guidelines can address all possible issues, only persons who have appropriate education and experience in chemistry and chemical safety should perform chemical demonstrations. Accordingly, these guidelines are intended for use only by experienced chemical practitioners.**

Before the Demonstration

1. Always follow a **tested, written procedure** that includes comprehensive safety precautions. Plan the demonstration at the smallest scale possible for the location and viewers.
2. **Review the safety precautions** which will help you identify the potential hazards involved in the demonstration and understand the risks due to exposure and/or improper handling of a chemical, process, or procedure. Effective safety precautions provide easy-to-follow instructions to minimize risk and prevent unplanned incidents that could result in injury or property damage.
3. If a written procedure is not available, or safety precautions are not clear, perform an independent **hazard and risk assessment** to identify the possible hazards and evaluate the risks. In the risk assessment, consider the pedagogical value compared to the risk. Write the demonstration procedure with appropriate safety precautions to protect against the hazards and reduce risk. Refer to these guidelines as you write the demonstration procedure, and retain the procedure on file for future use.
4. Always **practice** a demonstration before presenting it before students or an audience for the first time.
5. Ensure that all **demonstrations are appropriate for the room** being used and the available safety equipment. Keep all exit paths clear. Check the **ventilation** in the demonstration area to ensure that participants and audience members will not be exposed to harmful quantities of toxic gases or chemical vapors. The use of a **fume hood** is required for any demonstration that uses or produces a substance with a TLV less than 50 ppm (check the SDS for the TLVs of all chemicals).
6. Consult current **Safety Data Sheets** (SDS) and review the safe handling information for all chemicals used in the demonstration.
7. Prepare and follow a safety checklist for all **combustion demonstrations** involving the use of a flammable liquid. Dispense only the amount of the liquid required BEFORE beginning the demonstration. Cap the solvent bottle and REMOVE it from the demonstration area before applying the ignition source. NEVER add more flammable liquid to a combustion demonstration once it is underway.
8. Ensure that observers will be a **safe distance** (10 feet or more) or are protected by a physical barrier, such as a polycarbonate shield, from the demonstration area when working with flammable, corrosive or toxic substances. In a small setting such as a classroom or lab, all participants and observers must wear **appropriate eye protection** at all times.
9. Ensure there is an appropriate **fire extinguisher** on hand whenever the slightest possibility of fire exists and that you have the knowledge, experience and training to use it properly in the event of an emergency.
10. Keep a **spill kit** nearby to contain, absorb, and neutralize any spilled chemicals.
11. **Plan for appropriate handling or disposal** of reaction byproducts or excess chemicals in accordance with institutional policies.

During the Demonstration

12. Wear appropriate **personal protective equipment** (PPE) for the level of risk as determined by the assessment, such as chemical splash goggles, chemical-resistant gloves, and a lab coat, to protect against the hazards. Active participants must also wear appropriate PPE.
13. Provide **safety shield** protection whenever there is the slightest possibility that a container, its fragments or the contents could be propelled with sufficient force to cause exposure and/or personal injury.
14. **Warn** members of the audience to cover their ears if a loud noise is anticipated.
15. Participants and spectators must **not taste** any food or non-food substances used in the demonstration**.**
16. Do not perform demonstrations in which parts of the **human body** will be placed in danger (such as placing dry ice in the mouth or dipping hands into a hazardous liquid).

Special Notes for Outreach or Public Demonstrations

17. Ensure proper packaging and secondary containment for the **safe transport** of all chemicals to and from off-site locations. Materials of Trade (MOT) exceptions to Department of Transportation requirements allow for the transport of certain hazardous materials without a license or shipping papers provided certain guidelines are met. There are strict limits on the amounts of material, depending on the hazard. Visit the links below for more information about hazard classes, packaging requirements, and restrictions on the amounts of chemicals.
    https://hazmatonline.phmsa.dot.gov/services/publication_documents/MOTS05.pdf
    http://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/safetypractices/transporting-chemicals.pdf
18. **Notify** security and/or administrators that you will be performing demonstrations. If public space will be used for demonstrations involving fire, **contact the local fire department** to determine if the demonstrations meet local fire and building use codes.
19. Provide a **written demonstration procedure,** including comprehensive safety precautions and risk assessments, whenever the audience will be encouraged to conduct the demonstration at another time.

References

NFPA 45: Standard On Fire Protection For Laboratories Using Chemicals
http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=45

U.S. Chemical Safety Board: Key Lessons for Preventing Incidents from Flammable Chemicals in Educational Demonstrations http://www.csb.gov/key-lessons-for-preventing-incidents-from-flammable-chemicals-in-educational-demonstrations/

Prudent Practices in the Laboratory http://www.nap.edu/catalog/12654/prudent-practices-in-the-laboratory-handling-and-management-of-chemical

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Superintendents, Principals, Teachers . . . Do You Know the Law?

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It is the legal and professional obligation of all school personnel to provide a safe and healthy learning environment for students and staff. Administrators, staff and students are responsible for developing and following safety protocols and regulations in the science laboratory. Each must maintain a concerted effort to avoid the apathetic and laissez-faire attitudes which are a major cause of accidents in the laboratory. Effective laboratory safety is not possible without the continued education and commitment of all stakeholders involved in learning and experimentation in the scientific environment. The ability of students to solve problems using science inquiry is a vital step in the intellectual development of future educators, medical and science professionals and citizens in general. There is significantly more involved in ensuring science safety than merely presenting a set of rules and regulations to the class. Motivation, dedication and understanding of the "whys of safety" are essential in the development of a safe and effective school laboratory program.[1]

Legal issues of school laboratory safety are primarily determined by laws, codes, regulations and professional standards.

- A **law** is a statute enacted by a legislative body (e.g., The NC General Assembly). There are both federal and state laws that operate and regulate activity and behavior in the laboratory environment. In North Carolina these laws are referred to as General Statutes (GS) followed by a series of numerals or letters (e.g., GS §115C – Elementary and Secondary Education Act.
- A **code** becomes a law when it is either adopted by an existing statute or referenced by an existing code written under an existing statute (e.g., county, city, building, fire codes).
- A **standard** is the criteria by which something may be tested or measured. For instance, American National Standards Institute (ANSI) Z87.1 is the standard by which eye protection devices are measured.
- A **regulation** is a legislation promulgated by an administrative agency given this authority by a legislative body ((e.g., Occupational Safety and Health Administration (OSHA) 29 CFR §1910.1450)).

Occupational Safety and Health Act

When Congress passed the Occupational Safety and Health Act of 1970, it helped clarify and recognize many health and safety concerns. The purpose of OSHA is to ensure that employers provide a safe and healthy working environment for employees, including all teachers—public, charter and private. Although OSHA covers employees but not students, prudent school personnel will provide a safe and healthy learning environment for students by following federal, state and local health and safety codes / regulations.

Currently, OSHA (Occupational Safety and Health Administration) has approved state plans for 24 states and two territories. The state plan must be equal to or more stringent than the Federal OSHA Plan. Many OSH State-Plan states (North Carolina, South Carolina, and others) cover private and public sector employers / employees as required by Federal OSHA. North Carolina adopted the federal OSHA regulations as is except, North Carolina enacted more stringent permissible chemical exposure levels for employees. In addition, professional standards will always apply in terms of liability if an accident occurs.

There are over 100 OSHA standards that are applicable to K-16 schools – most requiring professional development for employees. Professional development is required before an employee reports to duty rather than after an accident occurs. While "after the accident" professional development may prevent future accidents, it does nothing to prevent accidents that have occurred or provide aid in liability protection for employers or employees. Key OSHA standards that effect schools requiring professional development for employees and a written program are:

- **29 CFR §1910.132 Personal Protective Equipment, General Requirements Standard**
  Requires a hazard assessment to determine PPE needs and employees must be trained in use and care of PPE. Teachers must also train their students.

- **29 CFR §1910.1030 (1991) Bloodborne Pathogens Standard**
  Employers are required to develop a plan to control bloodborne pathogen exposure (such as HIV and Hepatitis B) and universal precautions to prevent exposure to employees. All other body fluids are covered under this standard as well.

- **29 CFR §1910.38 Emergency Action Plan**
  Requires addressing of emergencies such as fire, toxic chemical spills releases, weather and weather related emergencies and others. Emergency evacuation routes and emergency action training is required for employees and, of course, students. Homeland security and many states have added requirements to address issues such as school violence and terrorism.

- **29 CFR §1910.1450 (1990) - Occupational Exposure to Hazardous Chemicals in Laboratories Standard,** OSHA defines a "Laboratory" as a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis." A hazardous chemical is defined as a "chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes or mucous membranes."

In addition to these standards, there is one standard that covers all hazardous conditions. This is known as the:
General Duty Clause (GDC), Section 5(a)(1) of theWilliam-Steiger OSH Act 29 CFR 654(a)(1):

"Each employer shall furnish to each of his (sic) employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees." OSHA inspectors can issue a citation to an employer for any workplace hazard not covered by other OSHA standards.

OSHA does classify schools as an industry. The Standard Industrial Classification (SIC) Code given to schools by OSHA is 8211. OSHA does inspect schools. These inspections are either random planned selection by NC OSH, complaint-based by an employee or parent or due to an accident. In 2007, NC OSH conducted 18 inspections in North Carolina schools citing 112 standards violations and assessed $22,007 in fines.[2]

The Laboratory Standard

State Board of Education

The State Board of Education required school systems to send a copy of their chemical hygiene plans (CHP) to the North Carolina Department of Education by January, 31, 2007. The chemical hygiene plan is not a requirement by the State Board of Education but a requirement of Federal and State Occupational Safety and Health Administrations (OSHA) as of January 31, 1991. Furthermore, this CHP is required for all middle and secondary schools. Elementary schools that have a separate laboratory for science also require a CHP. Many teachers believe they do not use chemicals or they are harmless because the chemicals they use are household chemicals. Household chemicals are also hazardous.

29 CFR §1910.1450 (1990) Occupational Exposure to Hazardous Chemicals in Laboratories Standard
This plan requires a CHO and details how each employee will be protected from overexposure to any hazardous materials, describes specific work practices and procedures in the laboratory to minimize employee risk, as well as the requirement of a Chemical Hygiene Plan, specifies laboratory safety and emergency equipment, employee information and training, hazard identification and recordkeeping. This regulation applies specifically to school science laboratories and must be followed as written to limit institutional and personal liability. Compliance to the requirements of this standard is mandatory. OSHA could site the school or LEA for a willful violation in the absence of a CHP or CHO.

OSHA 29 CFR §1910.1450(b)
designates the Chief Executive Officer (CEO) of an organization as the Chemical Hygiene Officer (CHO). The Superintendent of the School district is the CHO of the School district until a designee is appointed. The Principal of a school is the CHO of the school until a designee is appointed.

29 CFR §1910.1450(b) Regulation Defining CHO and Duties (Mandatory)
Chemical Hygiene Officer means "an employee who is designated by the employer—and who is qualified by training or experience—to provide technical guidance in the development and implementation of the provision of the Chemical Hygiene Plan. This definition is not intended to place limitations on the position description or job classification that the designated individual shall hold within the employer's organizational structure." School system administrators must acknowledge that the CHO is responsible for the safety of students and staff alike. To be an effective CHO, the school administrators must provide the CHO needed time, support and sufficient resources to do a thorough job.

The Superintendent is the Chief Executive Officer (CEO) of the School district and the Principal is the CEO of the school. The Superintendent of the School district is the CHO of the School district until a designee is appointed. The Principal of a school is the CHO of the school until a designee is appointed. The CHO designees must be knowledgeable of and qualified in the duties of a CHO rather than being "Volentold."

29 CFR §1910.1450(e)(3)(vii)
Designation of personnel responsible for implementation of the Chemical Hygiene Plan including the assignment of a Chemical Hygiene Officer and, if appropriate, establishment of a Chemical Hygiene Committee.

Hazard Communication Standard (Right-to-Know)

29 CFR §1910.1200 (1983) -

This standard applies to art, vocational education and all other areas of the school. Protection under OSHA's Hazard Communication Standard (HCS) includes all workers exposed to hazardous chemicals in all industrial sectors. Schools are classified by OSHA as an industry. This standard is based on a simple concept - that employees have both a need and a right to know the hazards and the identities of the chemicals they are exposed to when working. They also need to know what protective measures are available to prevent adverse effects from occurring. Hazards of chemicals must be conveyed on container labels and material safety data sheets (MSDSs). .It also provides necessary hazard information to employees so they can participate in and support the protective measures in place at their workplaces. All chemicals have associated hazards such as toxicity. Toxicity is determined by the dosage. Even water can be toxic as in the recent case of a California woman drinking more water in a given period then her body could assimilate. While harards cannot be removed, risks can be minimized.

CHP and HazCom Plans can be merged. There is about 80 % overlap between a CHP and HazCom Plan.

Employers who use toxic or hazardous substances must provide employees with:

- Chemical inventory, complete and updated at least annually
- Material Safety Data Sheets (MSDSs) which describe properties, safe handling and health hazards of materials for each chemical in the chemical inventory

- Labeling of all toxic substances with product name and hazard warning on every container and labeling of pipes (e.g., water, gas)
- Annual professional development on hazards of toxic substances, safe handling procedures and how to read MSDSs for all employees who work with hazardous chemicals.
- Written copy of HazCom program.

Professional / Industry Standards

In analyzing the duty of care owed by a teacher, school, etc. to take reasonable precautions to ensure the safety of employees and students, courts often look at industry standards to provide evidence of the standard of care in the specific industry. While these standards are not necessarily a definitive statement as to what the standard of care is for a particular industry—as the court must make the legal determination as to what the standard in the industry actually is for a particular set of facts—often the industry standard is the best evidence of what the standard of care should be ina particular situation. When industry groups reach consensus on a particular issue, such as the ANSI standard for eye wear, the court has a much easier task in reaching a decision, than when there is conflict in a standard.[3]

Summary

It is not an option for school systems or schools to obey federal, state and local laws, codes, regulations and standards which regulate school employees and science laboratories. Employers must provide science safety professional development for school personnel. The Laboratory Standard establishes needed science safety and emergency equipment for laboratories and requires a CHP. This standard is unique in also requiring a “qualified ”CHO. School superintendents and principals cannot pass their legal responsibility of being the CHO to another individual who is not qualified. The CHO must be given training and / or education, authority, financial support and time to implement an effective school laboratory safety program. For a more thorough discussion on Legal Issues, see the chapter on Legal Issues in Laboratory Safety in the Science Laboratory Safety Manual.

[1] Stroud, Linda M., Science Laboratory Safety Manual, Second Edition, 2008.

[2] www.osha.gov/oshstats/index.html “Search Inspections by SIC

[3] Kelly Ryan, Esq., author, *Science Classroom Safety and the Law.* Kelly Ryan Associates, Pasadena, CA.

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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. 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 1** **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

URL 25

NSTA Position Statement

Liability of Science Educators for Laboratory Safety

Introduction

Laboratory investigations are essential for the effective teaching and learning of science. A school laboratory investigation ("lab") is an experience in the laboratory, classroom, or the field that provides students with opportunities to interact directly with natural phenomena or with data collected by others using tools, materials, data collection techniques, and models (NRC 2006, p. 3). Inherent in laboratory-based activities is the potential for injury. Studies show that safety in K–12 school science instruction needs immediate and significant attention. (Gerlovich et al. 2005)

As professionals, teachers of science have a duty of care to ensure the safety of students, teachers, and staff. Duty of care is defined as an obligation, recognized by law, requiring conformance to a certain standard of conduct to protect others against unreasonable risk (Prosser et al. 1984). "The breach of a particular duty owed to a student or others may lead to liability for both the teacher and the school district that employs that teacher" (Ryan 2001). As such, science educators must act as a reasonably prudent person would in providing and maintaining a safe learning environment for their students.

Educators' duty to maintain a safe learning environment while providing science instruction also must be shared by school leaders, district administrators, school boards, parents, and students. It is vital that teachers and administrators communicate regularly and fully on the essentials of safe instruction for students.

Declarations

To ensure a safe and effective learning environment for students, teachers of science should:

- Integrate laboratory investigations into science instruction so that all students—including students with academic, remedial, or physical needs; gifted and talented students; and English language learners—have the opportunity to participate in laboratory investigations in a safe environment (NSTA 2007).

- Be proactive in seeking professional development opportunities to learn and implement practices and procedures necessary to conduct safe laboratory science investigations, including storage, use, and disposal of materials and chemicals; use of personal protective equipment; engineering controls; and proper administrative procedures (Roy 2006).

- Request and encourage school and district leadership to provide necessary professional development opportunities for staff and take personal professional responsibility to learn and implement these safe practices and procedures into teaching.

- Exercise reasonable judgment when conducting laboratory investigations.

- Accept the duty of care to provide all students and staff with a safe environment while performing hands-on science investigations or demonstrations in the laboratory, classroom, or field setting; using, storing, disposing/recycling, or transporting chemicals; or engaging in other related activities.

- Modify or alter activities in a safe manner, or select alternative activities to perform, when in the exercise of their duty, they determine that the proposed activities cannot be performed safely or a safe environment cannot be maintained.

- Identify, document, and notify school and district officials about existing or potential safety issues that impact the learning environment, including hazards such as class-size overcrowding in violation of occupancy load codes (BOCA 1996, ICC 2003, NFPA 2006) or contrary to safety research (West et al. 2005), inadequate or defective equipment, inadequate number or size of labs, or improper facility design (Motz et al. 2007), and give necessary recommendations to correct the issue or rectify a particular situation. Overcrowding has two research-based safety concerns: sufficient supervision and adequate individual workspace. Classes containing more than 24 students engaged in science activities cannot safely be supervised by one teacher. Additionally, research data show that accidents rise dramatically as class enrollments exceed 24 students or when inadequate individual workspace is provided (West et al. 2005).

- Communicate fully and regularly (at least once quarterly) with administrators regarding issues impacting the provision of safe science instruction.

- Share the responsibility with school district officials in establishing and implementing written safety standards, policies, and procedures, and ensure their compliance.

- Understand the scope of the duty of care in acting as a reasonably prudent person in providing science instruction, and acknowledge the limitations of insurance in denying coverage for reckless and intentional acts, as well as the potential for individual liability for acts outside the course and scope of employment. [*See generally*, Restatement (Second) of Torts §202. 1965; Anderson et al. 1999, p. 398.]

To ensure a safe learning environment, school district officials—such as administrators, principals, assistant principals, science supervisors, and superintendents—should:

- Understand that for science to be taught properly and effectively, lab activities—conducted in the laboratory, classroom, or field setting—must be integrated fully and safely into the science curriculum (NSTA 2007).

- Develop and implement comprehensive safety policies with clear procedures for engaging in lab activities. These safety policies should comply with all applicable local and state health and safety codes, regulations, ordinances, and other rules established by the applicable oversight organization, including the Occupational Safety & Health Administration (OSHA), International Code Council (ICC), Building Officials and Code Administrators (BOCA), and National Fire Protection Association (NFPA).

- Ensure that all safety policies, including those related to safety training, are reviewed and updated annually in consultation with school or district science educators.

- Support and encourage the use of laboratory investigations in science instruction, and share the responsibility with teachers to develop and fully integrate these activities into the science curriculum.

- Become knowledgeable of and enforce all local, state, and federal codes and regulations to ensure a safe learning environment for students and educators. Particular attention should be given to means of hazard prevention, including reasonable class sizes to prevent overcrowding in violation of occupancy load codes (BOCA 1996, ICC 2003, NFPA 2006) or contrary to safety research (West et al. 2005); replacement or repair of inadequate or defective equipment; adequate number or size of labs (Motz et al. 2007), or proper facility design; and the proper use, storage, disposal, or recycling of chemicals.

- Understand that the number of occupants allowed in the laboratory must be set at a safe level based on building and fire safety codes, size and design of the laboratory teaching facility, chemical/physical/biological hazards, and students' needs (NSTA 2000; Roy 2006). Science classes should have no more than 24 students to allow for adequate supervision during science activities, even if the occupancy load limit might accommodate more (NSTA 2004). It is equally important to ensure adequate workspace for each student. NSTA recommends 60 sq. ft. for each secondary student and 45 sq. ft. for each elementary student in a laboratory/classroom setting (Motz et al. 2007). Research data show that accidents rise dramatically as class enrollments exceed 24 students or when inadequate individual workspace is provided (West et al. 2005).

- Require teachers to develop, maintain, and implement chemical hygiene plans based on OSHA's Laboratory Standard criteria (OSHA 29 CFR 1910.1450) and Right to Know Standard (OSHA 29 CFR 1910.1200).

- Support teachers of science by obtaining materials and resources from national, state, and local organizations that will inform and educate teachers about safe laboratory activities, safety procedures, and best practices in the teaching of laboratory-based science instruction.

- Review existing insurance policies to ensure adequate liability insurance coverage for laboratory-based science instruction.

- Provide teachers with sustained, comprehensive training in lab logistics—including setup, safety, management of materials and equipment, and assessment of student practices—at the time of initial assignment and before being assigned to a new exposure situation (OSHA 29 CFR 1910.1450[f][2]). This includes storage, use, and disposal of materials and chemicals; use of personal protective equipment; engineering controls; and proper administrative procedures. To ensure ongoing safety, annual training should be provided to keep teachers well informed about changes in safety procedures (NSTA 2000).

- Support the decisions of teachers to modify or alter activities in a safe manner or select safe alternative activities to perform in the science classroom/laboratory.

- Maintain adequately supplied, properly equipped, and safe facilities for performing lab instruction by conducting annual facilities audits (Motz et al. 2007; Ryan 2001).

To ensure a safe learning environment, members of the school board should:

- Recommend and support upgrading and improving school science facilities and science curriculum/instruction. If possible, a districtwide review of science facilities and instruction should be conducted at least every 3–5 years.

- Ensure that the district has adequate insurance to cover liability claims arising in the science classroom/laboratory.

- Adopt districtwide policies for safety, including guidelines for a safe working environment for all employees.

Adopted by the
NSTA Board of Directors
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Additional Resources

Americans with Disabilities Act of 1990 (ADA). See *www.usdoj.gov/crt/ada/adahom1.htm* and *www.ada.gov/pubs/ada.htm.*

Building Officials and Code Administrators (BOCA). See *www.iccsafe.org/help/redirect-bocai.html.*

Individuals with Disabilities Education Act (IDEA). See *www.ed.gov/offices/OSERS/Policy/IDEA/index.html* and *www4.law.cornell.edu/uscode/20/1400.html.*

International Code Council (ICC). See *www.iccsafe.org.*

National Fire Protection Association (NFPA). See *www.nfpa.org.*

Occupational Safety & Health Administration (OSHA). U.S. Department of Labor. See *www.osha.gov.*

GHS at a Glance

1. Chemicals can be classified with health hazards (10 classes), physical hazards (17 classes), and/or environmental hazard hazards (2 classes) in the form of codes. The manufacturer or distributer must assign the codes based on very specific criteria. However, there will sometimes be variability on SDSs. Pubchem (NIH) has safety summaries that aggregate and show variations in classification (See Figure 2): https://pubchemdocs.ncbi.nlm.nih.gov/lcss
    a. Hazard codes (H codes) are short **succinct statements of hazard** which appear on the label of all chemicals now sold in the US. The actual code will often appear on the SDS in Section 2 (Figure 1)
    b. All codes are alphanumerical : H2xx (physical hazard); H3xx (health hazard); H4xx (environmental hazard)
2. Uniform throughout the system is the concept that the lower the category number within a particular classification, the greater the hazard is to the user. For example, being classified in a category as "1" indicates a greater hazard than being in a "2" category in the same class. You cannot compare across classes. H301 is a greater health hazard than H310.
3. There are nine pictograms that will be assigned as needed for the hazard class when a category reaches a certain criteria. Generally speaking, chemicals with pictograms assigned to them are higher hazard than those which did not meet the threshold to have one or more pictograms assigned. Some pictograms indicate a more significant hazard than others.
4. The signal word (danger or warning) is assigned for the greatest classification hazard. Only one signal word allowed. With multiple hazards you will not know which classification triggered the signal word without looking at the SDS.
5. Precautionary statements (P codes) are assigned based on the hazard codes that the chemical is assigned and they are succinct statements of response or protection.
    a. Sometimes these statements are combined, "IF"; "THEN" and sometimes the manufacturers forget to add the second part!
    b. All codes are alphanumerical: General precautionary statements (1xx); Prevention precautionary statements (2xx); Response precautionary statements (3xx); Storage precautionary statements (4xx); Disposal precautionary statements (5xx).
6. You can look this information up if you are so inclined!
    a. The Full Monty: The United Nations Economic Commission for Europe https://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html
    b. US: OSHA HAZCOM (1910.1200) and Appendices: https://www.osha.gov/dsg/hazcom/global.html
    c. Pubchem (NIH) has a listing of all the codes at: https://pubchem.ncbi.nlm.nih.gov/ghs/

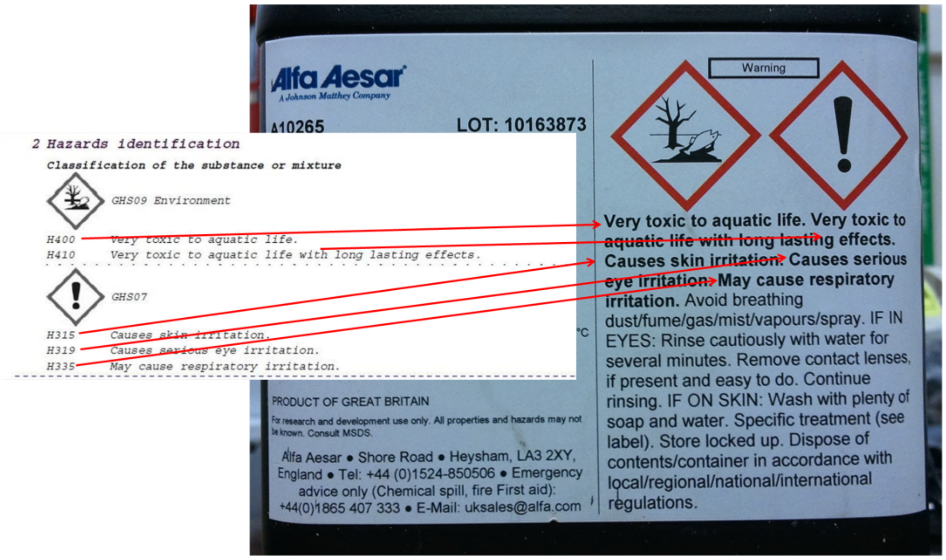
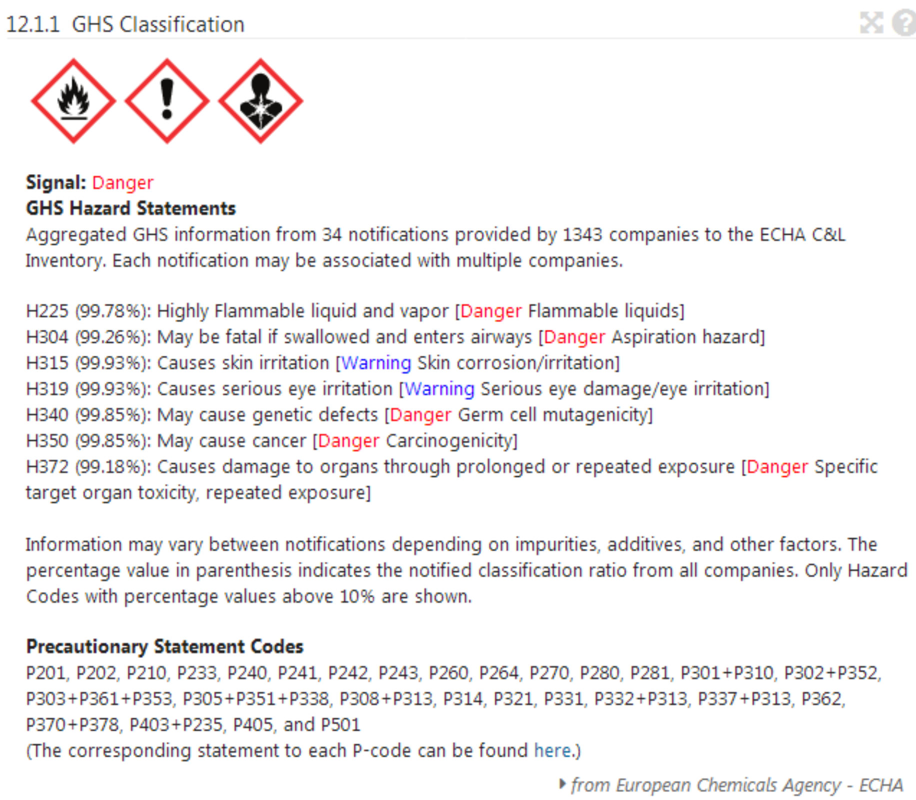


Figure 1- Sample Label and SDS Information



12.1.1 GHS Classification

Signal: Danger

GHS Hazard Statements

Aggregated GHS information from 34 notifications provided by 1343 companies to the ECHA C&L Inventory. Each notification may be associated with multiple companies.

H225 (99.78%): Highly Flammable liquid and vapor [Danger Flammable liquids]
H304 (99.26%): May be fatal if swallowed and enters airways [Danger Aspiration hazard]
H315 (99.93%): Causes skin irritation [Warning Skin corrosion/irritation]
H319 (99.93%): Causes serious eye irritation [Warning Serious eye damage/eye irritation]
H340 (99.85%): May cause genetic defects [Danger Germ cell mutagenicity]
H350 (99.85%): May cause cancer [Danger Carcinogenicity]
H372 (99.18%): Causes damage to organs through prolonged or repeated exposure [Danger Specific target organ toxicity, repeated exposure]

Information may vary between notifications depending on impurities, additives, and other factors. The percentage value in parenthesis indicates the notified classification ratio from all companies. Only Hazard Codes with percentage values above 10% are shown.

Precautionary Statement Codes

P201, P202, P210, P233, P240, P241, P242, P243, P260, P264, P270, P280, P281, P301+P310, P302+P352, P303+P361+P353, P305+P351+P338, P308+P313, P314, P321, P331, P332+P313, P337+P313, P362, P370+P378, P403+P235, P405, and P501
(The corresponding statement to each P-code can be found here.)

▸ *from European Chemicals Agency - ECHA*

Figure 2 - Aggregate Data from PubChem for Benzene

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Isopropyl alcohol; CAS 67-63-0

Classification	Category & Range	What does it mean?
Flammable liquids	Category 2 Range 1 to 4	Flash point* ≥ 23°C (73°F) and ≤ 60°C (140°F)
Eye irritation	Category 2A Range 1, to 2(A,B)	**(2)** Reversible adverse effects on cornea, iris, conjunctiva **(A)** Irritant Subcategory 2A Reversible in 21 days
Specific target organ toxicity - single exposure - Central nervous system	Category 3 Range 1 to 3	Transient target organ effects - Narcotic effects

*Flash Point – The lowest temperature at which a combustible liquid or solid produces sufficient vapor near its surface to generate an ignitable mixture with air.

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Nitric acid; CAS 7697-37-2

Classification	Category & Range	What does it mean?
Oxidizing liquids	Category 3 Range 1 to 3	Any substance or mixture which, in the 1:1 mixture, by mass, of substance and cellulose exhibits a pressure of rise time ≤ that of a 1:1 mixture of 65% HNO_3(aq) and cellulose
Skin corrosion	Category 1A Range 1, 1A to 1C	**(2)** Reversible adverse effects on cornea, iris, conjunctiva **(A)** Irritant Subcategory 2A Reversible in 21 days
Serious eye damage	Category 1 Range 1 to 2	Transient target organ effects - Narcotic effects

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Lead(II) nitrate; CAS 10099-74-8

Classification	Category & Range	What does it mean?
Oxidizing solids	Category 2 Range 1 - 3	Any substance or mixture which, in the 4:1 or 1:1 sample-to-cellulose ratio (by mass) tested, exhibits a mean burning time equal to or less than the mean burning time of a 2:3 mixture (by mass) of potassium bromate and cellulose and the criteria for Category 1 are not met.
Acute toxicity, Oral	Category 1 Range 1 - 5	$LD_{50} \leq 5$ mg/kg
Acute toxicity, Inhalation	Category 4 Range 1 - 5	$LC_{50} > 1.0 \leq 5$ mg/L
Serious eye damage	Category 1 Range 1- 2	Irreversible damage 21 days after exposure Draize score: Corneal opacity ≥ 3 Iritis > 1.5
Reproductive toxicity	Category 1A 1A/1B – 2 +	**Known** Based on human evidence
Specific target organ toxicity - repeated exposure	Category 2 Range 1 – 2	Presumed to be harmful to human health - Animal studies with significant toxic effects relevant to humans at generally moderate exposure (guidance) - Human evidence in exceptional cases
Acute aquatic toxicity	Category I Range I - III	Acute toxicity ≤ 1.00 mg/l
Chronic aquatic toxicity	Category I Range I - IV	Acute toxicity ≤ 1.00 mg/l and lack of rapid degradability and log $K_{ow} \geq 4$ unless BCF < 500

http://www.unece.org/trans/danger/publi/ghs/ghs_rev05/05files_e.html

	Range - Highest hazard to Lowest hazard
Explosives	Unstable Explosive > Div 1.1 > Div 1.2 > Div 1.3 > [1.4 - 1.5] > 1.6
Flammable Gases (+Chemically Unstable)	Category 1 > Category 2
	Category A > Category B
Flammable Aerosols	Category 1 > Category 2 > Category 3
Oxidizing Gases	Category 1
Gasses Under Pressure (classified by physical state when packaged)	Compressed gases, Liquefied gases, Refrigerated liquefied gases, Dissolved gases
Flammable Liquids	Category 1 > Category 2 > Category 3 > Category 4
Flammable Solids	Category 1 > Category 2
Self-Reactive Substances	Type A > Type B > Types C & D > Types E & F> Type G
Pyrophoric Liquids	Category 1
Pyrophoric Solids	Category 1
Self-Heating Substances	Category 1 > Category 2
Substances which, in contact with water emit flammable gases	Category 1 > Category 2 > Category 3
Oxidizing Liquids	Category 1 > Category 2 > Category 3
Oxidizing Solids	Category 1 > Category 2 > Category 3
Organic Peroxides	Type A > Type B > Types C & D > Types E & F> Type G
Corrosive to Metals	Category 1
Acute Toxicity (oral, dermal, inhalation)	Category 1 > Category 2 > Category 3 > Category 4 > Category 5
Skin Corrosion/Irritation	Category 1 > Category 1A > Category 1B > Category 1C > (Skin Corrosion)
	Category 2 > Category 3 (Irritation)
Serious Eye Damage/Eye Irritation	Category 1 (Serious Eye Damage)
	Category 2A > Category 2B (Eye Irritation)
Respiratory or Skin Sensitization	Category 1 (substance is classified as)
	Sub-Category 1A > Sub-Category 1B
Germ Cell Mutagenicity	Category 1 (A & B) > Category 2
Carcinogenicity	Category 1 (A & B) > Category 2
Reproductive Toxicology	Category 1 (A & B) > Category 2 > Additional Category
Target Organ Systemic Toxicity – Single Exposure	Category 1 > Category 2 > Category 3
Target Organ Systemic Toxicity – Repeated Exposure	Category 1 > Category 2
Aspiration Toxicity	Category 1 > Category 2
Hazardous to the Aquatic Environment	Short-Term (Acute) - Category 1 > Category 2 > Category 3
	Long-Term (Chronic - Category 1 > Category 2 > Category 3 > Category 4

Safety Data Sheet Considerations

- **No Data Available, Not Applicable, and N/A** – The phrase "No Data Available" should be viewed with some caution. It may mean that, in fact, there has not been any data reported about the property for that chemical, but it may also be that the person who wrote the SDS did not do their due diligence in locating available information. It may even be possible that the document was generated from a database of information by a computer. For common chemicals, there should be few (if any) "No Data Available" entries in Section 9 – Physical Properties. "Not Applicable" is used for those properties which do not apply to the chemical in the specified form. For example, one would not expect to see a melting or freezing point for a gas and in that case, "Not Applicable" should be reported.[41] "N/A" can mean either term, and is not a particularly useful for the SDS user.
- **Toxicological Data** – Look for the phase "Not Established" which is more meaningful than "No Data Available". The not established term is not ambiguous and tells the user that in fact the chemical has not been studied for the property.
- **Conflicting data** – Should there be conflicting data on an SDS, students can be instructed to review other sources of information or ask their instructor or advisor for guidance on what this might mean. There might be cases where two SDSs have disparate GHS information in Section 2 – Hazards Identification. This could depend on where the preparer got their information, or it may have to do with the concentration or form of the chemical being dissimilar. For clarification on this, PubChem Laboratory Chemical Safety Summaries (LCSSs) now show aggregated information by percent on reported variations of GHS information.[42] This allows the user to see which categories were most often assigned for the chemical.
- **Glove material –** Prior to GHS this information was rarely reported, but now it is recommended that the information be included.[42] However, even with the recommendation, the glove material may not be specified on a SDS. A thorough SDS will include glove material(s) for incidental splash and full immersion. ChemSafetyPro has produced a GHS SDS Preparation Tip sheet called "How to Select Gloves for Chemicals" that students can read.[43] While written to help those who prepare SDSs, it can also get students thinking about how to pick the correct glove material.
- **Odor Threshold (OT) vs. Permissible Exposure Limit (PEL) –** If the data is given compare the two. Ask students if they are going to be able to use smell as a warning property (i.e. PEL > OT). This can prompt discussion of whether or not smell is a good warning property. Regardless, remind students that if they can smell a chemical, they are being exposed.
- **Chemical Concentration, Form & Use –** Make sure that students understand that these can have a profound effect on the data given on the document. They should check Section 3 – Composition/Information on Ingredients for this information. If you are working with glacial acetic acid, you do not want a SDS for vinegar – or vice versa. You may even find a SDS that indicates a unique identifier for vinegar (CAS# 8028-52-2)[44] and compare that to another SDS that lists vinegar as a mixture of acetic acid (CAS# 64-19-7) and water (CAS# 7732-18-5). The hazards from a finely divided metal powder will be significantly different from those of a sheet of that same metal.

2 Hazard(s) identification

Classification of the substance or mixture in accordance with 29 CFR 1910 (OSHA HCS)

 *GHS07*

Acute Tox. 4 H302 Harmful if swallowed.
Hazards not otherwise classified *No information known.*

Label elements
GHS label elements *The product is classified and labeled in accordance with 29 CFR 1910 (OSHA HCS)*
Hazard pictograms

GHS07

Signal word *Warning*
Hazard statements
H302 Harmful if swallowed.
Precautionary statements
P264 Wash thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P301+P312 IF SWALLOWED: Call a POISON CENTER/doctor/.../if you feel unwell.
P330 Rinse mouth.
P501 Dispose of contents/container in accordance with local/regional/national/international regulations.
WHMIS classification *Not controlled*
Classification system
HMIS ratings (scale 0-4)
(Hazardous Materials Identification System)

HEALTH	2	*Health (acute effects) = 2*
FIRE	1	*Flammability = 1*
REACTIVITY	1	*Physical Hazard = 1*

Other hazards
Results of PBT and vPvB assessment
PBT: *Not applicable.*
vPvB: *Not applicable.*

2.2. Label elements


Signal Word **Danger**

Hazard Statements
H228 - Flammable solid
H301 - Toxic if swallowed

Precautionary Statements
P280 - Wear protective gloves/ protective clothing/ eye protection/ face protection
P302 + P352 - IF ON SKIN: Wash with plenty of soap and water
P210 - Keep away from heat/sparks/open flames/hot surfaces. - No smoking
P301 + P310 - IF SWALLOWED: Immediately call a POISON CENTER or doctor/ physician

2 Hazard(s) identification

· ***Classification of the substance or mixture***

 *GHS06 Skull and crossbones*

Acute Tox. 3 H301 Toxic if swallowed.

· ***Label elements***
· ***GHS label elements*** *The substance is classified and labeled according to the Globally Harmonized System (GHS).*
· ***Hazard pictograms***

GHS06

· ***Signal word*** *Danger*

· ***Hazard-determining components of labeling:***
Dimethylglyoxime
· ***Hazard statements***
Toxic if swallowed.
· ***Precautionary statements***
If medical advice is needed, have product container or label at hand.
Keep out of reach of children.
Read label before use.
Wash thoroughly after handling.
Do not eat, drink or smoke when using this product.

(Contd. on page 2)

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Flammable solids (Category 2), H228

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram 

Signal word	Warning
Hazard statement(s)	
H228	Flammable solid.
Precautionary statement(s)	
P210	Keep away from heat/sparks/open flames/hot surfaces. No smoking.
P240	Ground/bond container and receiving equipment.
P241	Use explosion-proof electrical/ ventilating/ lighting/ equipment.
P280	Wear protective gloves/ eye protection/ face protection.
P370 + P378	In case of fire: Use dry sand, dry chemical or alcohol-resistant foam to extinguish.

7.1.1 GHS Classification

Signal: Danger

GHS Hazard Statements

Aggregated GHS information from 8 notifications provided by 36 companies to the ECHA C&L Inventory. Each notification may be associated with multiple companies.

H228 (86.11%): Flammable solid [Danger Flammable solids]
H301 (77.78%): Toxic if swallowed [Danger Acute toxicity, oral]

Information may vary between notifications depending on impurities, additives, and other factors. The percentage value in parenthesis indicates the notified classification ratio from all companies. Only Hazard Codes with percentage values above 10% are shown.

Precautionary Statement Codes

P210, P240, P241, P264, P270, P280, P301+P310, P321, P330, P370+P378, P405, and P501
(The corresponding statement to each P-code can be found here.)

▸ *from European Chemicals Agency - ECHA*

Risk Assessment

DETERMINE HAZARDS

CHEMICALS
HEALTH, PHYSICAL, & ENVIRONMENTAL

Health

Physical

Environmental

PROCEDURAL
UNCONTROLLED ENERGY, MECHANACAL, & ENVIRONMENT

FIND INFORMATION

American Chemical Society

- Chemical Safety in the Classroom
- Committee on Chemical Safety
- Division of Chemical Health & Safety
- Division of Chemical Education Safety Committee
- Association of American Chemistry Teachers
- Hazard Assessment

NSTA Safety in the Science Laboratory
NIH Lab Safety

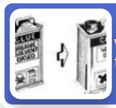
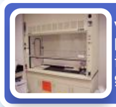
UNDERSTAND RISK

Likelihood is a measure of how likely the occurrence of a complete sequence of events leading up to a consequence is based upon exposure to a hazard	• This component is often associated with descriptors such as: rare; unlikely; possible; likely; almost certain
For chemicals, **exposure** must consider the nature of the chemical and how it is being used	• Consider toxicity, route of entry, chemical form, length of exposure, etc. • Do not forget the physical hazards of chemicals and processes
Severity of **consequence**	• Medical treatment • Cost

Risk Estimate = (Likelihood x Exposure x Consequences)
\+ **Human Factors such as a new worker**

CONTROL HAZARDS to LOWER RISK

Control Hierarchy Effectiveness

Elimination		The initial design of the facility, equipment, chemicals or process to remove hazards
Substitution		Water based solvent vs. organic , lower reaction temp or pressure, less toxic reactants, etc.
Engineering		Ventilate or isolate with timing, hoods, gloves boxes, bio safety cabinets, snorkels, safety interlocks, lead shielding, inert atmospheres, guarding, etc.
Administrative		Implementation of procedures and policies (SOPs, LOTO), training, reducing exposure times, attention to susceptible employees, signage, best work practices, not working alone, etc.
Personal Protective Equipment		Gloves, respirators, aprons, lab coats, goggles, ear plugs, face shields, etc.

FIVE IMPORTANT QUESTIONS TO ASK AND ANSWER IN A RISK ASSESSMENT

Are there specific chemical or physical reactivity hazards associated with the use of the chemicals involved?

Identify processes that will where energy is involved temperature, pressure, electricity, mechanical, etc.)

Look at the label on the chemical bottle and review the GHS information given

Focus on the processes and chemicals with higher risk

Does the work require the use of a fume hood or other local ventilation system?

Look for substances with low (<50ppm) permissible exposure limits (PELs)on SDSs

Look for phases such as, "Use with adequate ventilation"

What personal protective and other safety equipment is appropriate for the chemicals and processes in this experiment?

Primarily gloves, goggles, & lab coats

For maximum effectiveness, research must be done to find correct material, correct type and ensure correct fit.

Remember if personal protective equipment fails: you have exposure!

Are there unusual emergency response protocols necessary for this experiment?

Are there additional hazard specific protocols beyond best practices that must be in place for using the chemicals?

Is additional hazard specific equipment required beyond that required in a chemistry laboratory?

What should I do with chemical and other wastes I generate?

Determine what waste will be considered "hazardous" according to local regulations

Determine container compatibility

Pre-label containers for anticipated waste

Assessing Risk: *Five Key Questions for Safe Research and Demos*

BY SAMUELLA SIGMANN AND RALPH STUART

After you have taken a couple of chemistry classes, it might seem that the safety rules you reviewed on the first day ("Wear your goggles", "Use the hood when you need to") told you everything you need to know about working safely with chemicals.

When you start working with chemicals on your own — whether in a research lab or in a chemistry demonstration before an audience — the safety situation changes. In teaching labs, someone has already identified the hazards and lowered the risks as much as practical prior to your arrival. But research work requires that you explore new ideas and deviate from established experiments, which can introduce new hazards.

Meanwhile, chemistry demonstrations can take place outside the controlled environment of the lab, which can expose both you and your audience members to a variety of new risks.

Both ethics and self-preservation require you to consciously consider what unexpected results might arise in either situation (see The Chemical Professional's Code of Conduct at **www.acs.org/content/acs/en/careers/career-services/ethics/the-chemical-professionals-code-of-conduct.html**).

There are legal implications, too. Many states adhere to the National Fire Protection Association's recommendation that educators conduct documented risk assessments prior to demonstrations or when students are using hazardous materials in laboratories.[1]

Learning to assess and address risk is vital to your academic and professional career.

The following five questions will help you develop your risk assessment skills and increase your understanding of chemical hazards. You should always document your answers to these questions in writing so that you can explain them to others as the need arises.

1. *What specific chemical or physical reactivity hazards are associated with the way I'm using these chemicals?*

Risk assessment starts with finding reliable information about your chemicals (see Recommended Websites for Researching Chemical Safety Data on page 8), but you should also consider how you are using them. Sometimes simple substitutions of the chemicals in a process or changing the amount or concentration of the chemicals being used can create a different risk scenario.

Explosions at the University of Minnesota and Texas Tech University are evidence of the hazards associated with even small changes in the chemistry being studied.[2, 3]

Safety Data Sheets (SDSs) don't always provide specific information about these changes because manufacturers of chemicals can't predict all the ways researchers will use them. Remember that the phrases "Not Available" and "No Information" do not mean "Safe." Consulting information resources beyond the SDS is important any time you (1) change the chemical or process you're using, (2) increase the concentration of the chemicals you're using, or (3) increase the quantities of the chemicals you're using by a factor of 3 or more.

For physical hazards associated with chemicals, be particularly mindful of chemicals that have a signal word "Danger" with the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) icon of an exploding bomb, oxidizer, or corrosive. For health hazards, be particularly mindful of the skull and crossbones and health hazard icons. If chemicals with these warnings are important to your experiment, be sure to take protective measures, such as using only small quantities and carefully controlling what the chemicals come into contact with.

2. *What type of ventilation do I need?*

In the laboratory, both fume hoods and general room ventilation rely on dilution to control the potentially hazardous vapors from chemicals. If there are likely to be significant emissions of chemicals that you don't want to breathe, you need a fume hood. Remember that fume hoods have to be used correctly to contain vapors and are not meant to control fires, explosions, or particles.[4]

So which chemicals don't you want to breathe? For help in making this determination, consult the SDS to identify toxicity levels and odor thresholds of the chemicals. Look for the phrase "well-ventilated space" in the SDS precautionary statements. Seek advice from your advisor or chemical hygiene officer if you do not know how the data you find apply to ventilation requirements.

Risk Assessment in the Workplace

In industry, "risk assessment" is the process of identifying, evaluating, and mitigating hazards. A grid similar to the one shown below is typically used to estimate risks.

The impact of something going wrong (organized in columns) is combined with the likelihood of it happening (in rows), and a relative risk level is assigned accordingly. For example, if someone is dissolving sodium chloride in boiling water using a stirring rod, an accidental splash is somewhat likely. A boiling- water splash will probably burn (recognized hazard), so this procedure comes with a moderate risk.

LIKELIHOOD	IMPACT: Negligible	Harmful	Serious
Very likely/ frequent	Moderate risk	High risk	High risk
Somewhat likely	Low risk	Moderate risk	High risk
Unlikely	Low risk	Low risk	Moderate risk

In the workplace, low-risk procedures are preferred. The aforementioned procedure could be made less risky by modifying it to use a stir plate or room-temperature water, for example. Moderate-risk activities are considered carefully, with emergency plans in place ahead of time. High-risk procedures are rarely, if ever, approved because they do not meet legal or code requirements without expensive engineering precautions. iC

3. *What personal protective equipment do I need?*

This is probably the most complicated of the safety questions. First, you must decide what personal protective equipment (PPE) is required for the chemicals and the processes you are using. Your specific PPE needs will depend on how the work is being done.

Consider the following:

Fit. Take the time to find the right size protective equipment for you. If your audience members will need PPE, be sure to have a variety of sizes. Changing the brand may provide a fit.

Gloves. The width of your hand across your knuckles, in inches, is your approximate glove size. Gloves should be tight enough to move with you and keep out hazards, but they should not be so tight that they tear easily or weaken the material.

Eyewear: Goggles should provide a complete, snug seal around the eyes and the bridge of your nose. If they are too loose, hazardous liquids could splash in. If they are too tight, they may fog. If you wear eyeglasses, look for goggles sold as "OTG" (over the glasses).

Lab coat. A lab coat should cover from your arms to your wrist and fall past your knees. It should be just large enough to cover your torso when fastened without gapping or restricting movement. Loose sleeves can create a spill hazard; rolled-up sleeves can trap chemicals. A lab coat that is too large can trip you, become caught on equipment, or leave your neck area open for spills.

Type. Generally, if there is a possibility of a chemical splash of more than 100 mL, then you need chemical splash goggles with indirect venting. If you are using instrumentation or doing computer work in the lab, safety glasses may suffice.

Material. Chemicals can permeate all glove materials, eventually. The "permeation time" can help you decide which material is best for your chemicals. If you cannot find a specific material for your chemical, it may make sense to wear two pairs of gloves and replace the outer gloves whenever they show signs of contamination or tears. Likewise, when working with flammable solvents or demos that involve fire, you need a flame-resistant coat that provides coverage to, at least, the knees. A rubber apron might be needed if you are working with larger quantities of corrosive liquids.

4. *What emergency response protocols will be needed if something goes wrong?*

Chemistry laboratories will have spill kits, fire extinguishers, eyewashes, and safety showers available — but do you know how to use them? An emergency is not the time to figure out how they work, so ask your faculty advisor for a chance to try them before you need them.

Working with certain chemicals requires special planning in case of a spill or exposure. Some chemicals can penetrate the skin's surface and impact other organs of the body, such as the kidneys, heart, and nervous system. Deaths have resulted when lab workers spilled very hazardous chemicals on their skin and lacked the proper first-aid resources to treat the exposure. Look for the phrase "Specific Target Organ Toxicity" on the SDS for any chemical marked with the GHS skull and crossbones icon to identify chemicals with this potential. Whenever using such chemicals, special training, adequate ventilation, and the correct PPE are imperative for safe use.

Ball State University Regional Science Fair

5. *What will I do with the waste?*

Laboratory work can generate many different kinds of wastes. Some of the most common among them are chemicals, sharps, biological wastes, and radioactive wastes. For practical and legal reasons, these cannot be disposed of in the sink, trash, or recycling system. Very little information on this topic will be present on SDSs because laboratory wastes are regulated differently from location to location. For this reason, your institution will have its own system to ensure the safe collection and disposal of hazardous wastes. Labeling of waste is strictly regulated by the Environmental Protection Agency, so it's important that you understand your institution's requirements.

Be sure to know which protocols apply to any waste materials you will generate before you start work. The mixing of incompatible materials in waste containers is very dangerous and can result in the container rupturing. As with an emergency, you don't want to be thinking "Where does this go now?" or "Can I mix these?" after you have already generated the waste.

After taking a couple of chemistry courses, you are probably feeling pretty safe around chemicals; however, recent fires, explosions, and other incidents should remind you that even familiar materials can become dangerous if you are not prepared. Fortunately, learning to ask and answer the questions listed above before proceeding with laboratory work or chemical demonstrations during your undergraduate years will advance your thinking about safety from merely following rules to managing risk. This good habit will be a powerful advantage as you make the transition from a student in teaching labs to a chemist in research and demonstration settings. iC

Samuella Sigmann *and* **Ralph Stuart** *serve on the ACS Committee on Chemical Safety. Sigmann is the chemical hygiene officer for the chemistry department and an analytical chemistry lecturer at Appalachian State University (NC). Stuart is the chemical hygiene officer at Keene State College (NH) and Secretary of the ACS Division of Chemical Health and Safety.*

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Chemical Safety Data Resources

Laboratory Chemical Safety Summary (LCSS) in PubChem
https://pubchem.ncbi.nlm.nih.gov/lcss
Developed by the National Center for Biotechnology Information

CAMEO Chemicals
https://cameochemicals.noaa.gov
Set up by the National Oceanographic and Atmospheric Administration

Safety Resources

Hazard Assessment in Research Laboratories
A collection of methods and tools for assessing hazards in research laboratories
www.acs.org/hazardassessment

The Safety Zone
Covers chemical safety issues in academic and industrial research labs as well as in manufacturing
http://cenblog.org/the-safety-zone

Lab Safety Quiz
A quiz based on the ACS pamphlet *Safety in Academic Chemistry Laboratories*
www.stolaf.edu/depts/chemistry/safety

FITS LIKE A GLOVE

Choosing the Right Glove for the Job

What part of your body is most exposed to chemicals in lab work and demos?

Your hands, of course!

Protecting them with gloves is quick and easy, if you know which type to use.

POLYETHYLENE

Advantages:
- Excellent protection from common acids and bases
- Inexpensive

Disadvantages:
- Limited tear resistance

Good protection from:
- Acids
- Detergents
- Common dilute lab reagents

Poor protection from:
- Concentrated reagents and solvents

NEOPRENE

Advantages:
- High density
- Tear resistant

Disadvantages:
- Impaired dexterity

Good protection from:
- Peroxides
- Fuels
- Alcohols
- Organic acids and bases

Poor protection from:
- Halogenated compounds
- Aromatic compounds

NITRILE

Advantages:
- Flexible
- Sturdy
- Easy to see punctures

Disadvantages:
- Limited chemical protection

Good protection from:
- Oils and greases
- Acids, caustics
- Alcohols
- Chlorinated solvents

Poor protection from:
- Strong oxidizing agents
- Aromatic solvents
- Ketones
- Acetates

BUTYL

Advantages:
- Sturdy
- Reusable

Disadvantages:
- Limited sizes
- Impaired dexterity

Good protection from:
- Peroxides
- Strong acids and bases
- Alcohols
- Aldehydes
- Ketones
- Esters
- Nitro compounds

Poor protection from:
- Hydrocarbons (aliphatic, aromatic)
- Halogenated solvents

LAMINATE FILM

Advantages:
- Protection from a wide variety of chemicals
- Can be a liner under other gloves
- Good dexterity
- Good for hazmat work

Disadvantages:
- Not puncture-resistant

Good protection from:
- Alcohols
- Hydrocarbons (aliphatic, aromatic)
- Chlorines
- Ketones
- Esters

Poor protection from:
- Check manufacturer information

Individual brands vary. Always check glove compatibility against the manufacturer's recommendations.

Special thanks to the ACS Committee on Chemical Safety.

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www.osha.gov/Publications/osha3151.html
www.ehs.berkeley.edu/workplace-safety/glove-selection-guide

JOURNAL OF CHEMICAL EDUCATION

Communication

pubs.acs.org/jchemeduc

Using Elephant's Toothpaste as an Engaging and Flexible Curriculum Alignment Project

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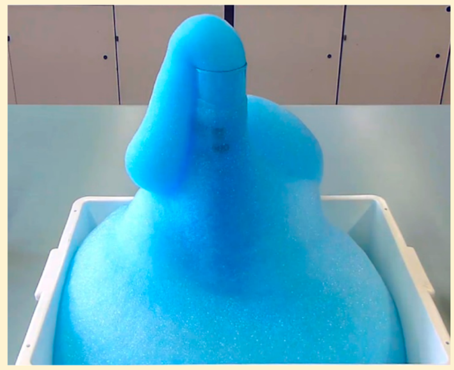
Supporting Information

ABSTRACT: There is an increasing focus across all educational sectors to ensure that learning objectives are aligned with learning activities and assessments. An attractive approach previously published is that of curriculum alignment projects. This paper discusses the use of the fun and famous "Elephant's Toothpaste" experiment as a customizable curriculum alignment project that can be tailored to address a large number of learning activities and learning outcomes in chemistry suitable for students ranging from late high school through to first year university.



KEYWORDS: *High School/Introductory Chemistry, First-Year Undergraduate/General, Demonstrations, Inquiry-Based/Discovery Learning, Applications of Chemistry, Catalysis, Thermodynamics, Gases, Kinetics, Stoichiometry*

■ INTRODUCTION

Modern pedagogy places a strong emphasis on the need for curriculum alignment. Mapping activities should be conducted in order to ensure that each learning objective has a linked learning activity in order to teach the objective and a corresponding assessment so that both the student and educators are able to see that the learning objective has been met.[1−4]

There are many ways of achieving these goals as part of an active, engaging learning environment. One appealing method for achieving this is the use of a Curriculum Alignment Project (CAP). A CAP was originally suggested as a demonstration or experiment conducted at the beginning of a course which demonstrated a multitude of learning objectives to be included as part of the unit of study. As the unit proceeds and the students' body of knowledge grows, they are able to readdress the CAP and comprehend or explain more and more of the activity.[5,6]

Previous researchers have surveyed students and found that many believe that learning involves the accumulation and memorization of information followed by exhibiting the ability to reproduce that information on demand for assessments.[7] Few students see new information as pieces to be incorporated into an ever-growing body of knowledge that they possess. A CAP allows students to observe how individual pieces of knowledge contribute to the whole. Showing students a link between a learning objective and a practical application increases student motivation.[8]

This paper demonstrates the use of a famous and entertaining experiment—Elephant's Toothpaste—as a CAP. Students thoroughly enjoy the spectacle of the experiment, making it an ideal choice for an activity to frequently relate content to. The experiment is simple to conduct, but grand enough that it can be done as a demonstration on a large scale, or scaled down and conducted by the students themselves. As such, variations of this experiment make for popular demonstrations.[9−13]

There are a large number of fundamental chemical concepts that can be discussed in relation to this experiment. Each concept can be explored or bypassed according to the learning objectives set by the instructor. As such, this flexible CAP is appropriate for students ranging from high school chemistry through to first year university.

■ SAFETY AND EXPERIMENTAL CONSIDERATIONS

A lab coat, safety glasses, and closed shoes should be worn at all times. The 30% w/v hydrogen peroxide (H_2O_2) solution is both corrosive and a strong oxidizing agent. Handle with care and wear gloves at all times.

The reaction is quite exothermic. To prevent heat burns, take care not to touch the measuring cylinder during the reaction.

If spills occur and result in staining with I_2, this can easily be cleaned up using ~0.1 M $Na_2S_2O_3$. In fact, this cleanup is also an excellent practical application of redox chemistry!

This method describes the decomposition of 100 mL of 30% w/v hydrogen peroxide solution. This is effective for a spectacular demonstration, presented to a classroom or small lecture theater. If the experiment is to be conducted by

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Table 1. Skills, Activities, and Assessment Points That Can Be Addressed during the Curriculum Alignment Project

Skill/Objective	Activity/Observation
Occupational health and safety	Observe the use of safety equipment, relate to SDS and/or risk assessments.
Reaction writing and balancing	Observe the occurrence of the reaction and, if possible, predict the products formed. More junior chemists could be encouraged to simply balance the equation.
Lewis structures	Draw Lewis structures for both the reactants and products of the reaction, giving experience with single and multiple bonds as well as lone pair electrons.
Mass and % w/v	Determine the mass of H_2O_2 present in a given volume of 30% w/v solution.
Molarity, volume, and molar mass	Use the molarity and volume to find the number of moles and/or mass of H_2O_2 used.
Gas stoichiometry and the ideal gas equation	Use the quantity of H_2O_2 available to predict/determine the mass or volume of oxygen gas produced through use of the ideal gas equation.
Comparing the density of solids and liquids to gases	Observe the fact that a very large volume of gas is created from a small quantity of solid and liquid. Note that this is true despite the fact that it takes 2 mol of H_2O_2 to produce 1 mol of O_2.
Endothermic and exothermic reactions	Measure the change in temperature and/or use this in conjunction with the observation of steam to conclude the nature of the reaction.
Calorimetry, enthalpy, and thermochemical equations[a]	Use the change in temperature during the reaction to calculate the amount of energy released by the reaction and/or the enthalpy of reaction.
Catalysts	Observe the rate of decomposition of H_2O_2 before and after being combined with KI.
Redox[b]	Observe the occurrence of the reaction upon the addition of KI. Potentially notice the subtle brown discoloration caused by the formation of I_2 from I^-. This is more pronounced in the absence of the food dye (see the photo provided in the Supporting Information).
Redox	Observe that any brown stains formed during the experiment do not easily clean off with water. However, upon application of $Na_2S_2O_3$ solution, the stain is easily cleaned as I_2 is reduced to I^-. $2S_2O_3^{2-}$ (aq) + I_2 (aq) → $S_4O_6^{2-}$ (aq) + $2I^-$ (aq)
Kinetics[c]	Repeat experiments can be used to determine the order of reaction and the rate law.

[a]A paper discussing this skill in great detail has been presented elsewhere.[10] [b]A paper discussing this skill in great detail has been presented elsewhere.[11] [c]A paper discussing this skill in great detail has been presented elsewhere.[11,12]

individuals or small groups of students, scaling down the volumes and/or concentrations may be appropriate in order to decrease the quantity of chemicals consumed and to diminish the chances of any chemical burns.

The experiment could even be conducted by students out of class, using yeast as the catalyst, dish soap as the surfactant, and 3% hydrogen peroxide solution, which can be purchased at a pharmacy. If the experiment is to be primarily conducted by students, other modifications have been suggested in the literature that would further minimize the risks associated with the handling of the chemicals involved.[9]

■ METHOD

A 100 mL portion of 30% w/v hydrogen peroxide is premeasured into a capped plastic bottle. To begin, the demonstrator may remove the cap to show that "nothing happens" because the decomposition is slow.

In a 500 mL measuring cylinder, place ~2.5 g of KI. This acts as a catalyst and is a substantial excess. If KI is unavailable, other simple iodide salts, yeast, or $Fe(NO_3)_3$ may be used instead.[10]

Next, add ~20 mL of concentrated surfactant (e.g., Pyroneg). If it is not of suitably high concentration, the volume of gas captured will be insufficient to carry the demonstration.

If desired, add ~3 mL of food coloring. This is purely for aesthetics.

Place the measuring cylinder in a sink or large container (at least 15 L is recommended). When ready, add the entire volume of H_2O_2 solution to the measuring cylinder. As oxygen gas is produced, a large volume of foam will be created that will very quickly exceed the capacity of the measuring cylinder and overflow into the container. The reaction proceeds according to the following chemical equation:

$$2H_2O_2\ (aq) \rightarrow 2H_2O\ (l) + O_2\ (g)$$

A video of the demonstration is supplied in the Supporting Information. If desired, a small variation can be applied where the catalyst is added as the final ingredient to highlight the role that it plays.

■ RESULTS AND DISCUSSION

The demonstration creates a large volume of foam, as the hydrogen peroxide decomposes to form water and half as many moles of oxygen gas, which, in conjunction with the surfactant, makes bubbles. Using these quantities, approximately 13 L of gas is produced, although the amount captured varies depending on the concentration of surfactant and hydrogen peroxide used (H_2O_2 goes "off"—decomposes—over time). Table 1 details the major learning objectives that the experiment could demonstrate, along with relevant observations or activities for students in order for them to capture the learning objective. There is great flexibility in which of these learning objectives an instructor may wish to use, as many of them are independent of one another.

In regard to how these observations and activities are aligned with an assessment, any number of possibilities exist. Assessment activities could be run on a weekly basis after the demonstration so that their knowledge of the reaction grows continuously. The assessment could be saved for the end of the unit, where a section of their final assessments could be dedicated to their understanding of the experiment. Alternatively, the CAP could be flipped around: the demonstration could be unveiled at the end of the unit of study before then asking students to use their new-found skills to describe the experiment. Regarding the nature of the assessment, conventional written tasks based on the key concepts could be employed, as authors have noted that problem solving exercises can themselves embody constructive alignment.[2] Furthermore,

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some students reflect on their performance on a written test as being an indicator of their understanding of the concepts, and sometimes more important than the success in terms of awarding marks.[7]

Alternative assessment techniques could include a verbal presentation of a given learning objective, an audio recording of the student's understanding, the development of a multimedia presentation which could then be uploaded and used as a student study resource, or really, any other mode that the instructor wishes. The degree of difficulty of the assessment can be tailored to suit the level of the students for most of the suggested objectives.

■ CONCLUSIONS

This paper outlines how the Elephant's Toothpaste experiment provides the possibility of a fun and engaging curriculum alignment project. No fewer than 13 key chemistry skills (learning objectives) have been identified as being observable, instructive, and, if desired, assessable within the demonstration.

■ ASSOCIATED CONTENT

Supporting Information

A video demonstration of the Elephant's Toothpaste experiment is supplied. An audio-free version of the same video is provided for those who may want to use it for a virtual demonstration. A photo of the experiment conducted in the absence of food coloring is shown to highlight the formation of I_2 to instructors interested in pursuing this learning objective. A few examples of learning activities and questions used in relation to this experiment are also provided. This material is available via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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I would like to thank Marylou Molphy, Ian Harding, and Russell Crawford for their mentoring of my teaching practices.

■ ABBREVIATIONS

CAP, curriculum alignment project; % w/v, percent weight-volume (grams per 100 mL)

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Demonstration Risk Assessment
"Elephant's Toothpaste"

Prepared By: Samuella Sigmann **Date Prepared:** July 16, 2016 **Date Revised:** July 11, 2017

Demonstration Statement

A slightly yellow solution is created in a 1 L cylinder with hydrogen peroxide (H_2O_2) is mixed with Joy dish soap.[1] When a scoop of potassium iodide (KI) is added to the cylinder, a foam resembling toothpaste rises out of the opening. As KI catalyses the rapid decomposition of H_2O_2 and in the presence of soap the rapidly generated oxygen from the decomposition will create mounds of fine suds filled with oxygen gas.

The Chemistry

The reaction proceeds nearly immediately once the KI is added. The reactions for the decomposition are shown here.

H_2O_2 + ~~I^- (aq)~~ → H_2O (l) + ~~OI^- (aq)~~

H_2O_2 (aq) + ~~OI^- (aq)~~ → H_2O (l) + O_2 (g) + ~~I^- (aq)~~

---

2 H_2O_2 (aq) → 2 H_2O (l) + O_2 (g) + heat

Reactivity Hazards

Known Incompatibilities

- hydrogen peroxide (SA SDS): zinc, powdered metals, copper, nickel, brass, iron and iron salts.
- potassium iodide (BDH SDS) strong reducing agents, Nickel, Strong acids, and its alloys, Steel (all types and surface treatments), Aluminum, Alkali metals, Brass, Magnesium, Zinc, cadmium, Copper

Information Sources Used and/or Reviewed

- Potassium Iodide: Sigma Aldrich SDS, product #221945, Version 4.10 Revision Date 12/02/2015.
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[1] Any dish soap can be used, but Joy works the best for generating the desired size of bubbles. The hazards are not affected.

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Equipment Required with Known Hazards

Spill tray, 1 L cylinder (sharps), scoopula

Safety and Emergency Response Equipment

For ER:

- No unusual ER equipment is needed. Standard laboratory ER equipment (including fire extinguisher) should be available. If demo is performed as outreach or in the classroom, include portable bottle of eyewash solution. Avoid performing outside if windy.

For Spills:

- Small amounts of H_2O_2 can be cleaned up by diluting liberally with water and then absorbing on wet paper towels using nitrile gloves. Rinse prior to placing in the trash can. Avoid inhalation.
- KI spills should be gathered up with a small broom and dust pan and dissolved in a beaker of water. Solutions with pH between 5 and 9 can be drained disposed in most areas. Check local regulations.

PPE

Chemical splash goggles, nitrile gloves, lab coat (optional)

Preparation Instructions with Associated Hazards & Controls

Gather chemicals and equipment. There are no known hazards other than breaking glass or spilling reagents while gathering equipment. See demonstration procedure for those controls.

Table 1: Information for Reagent Preparation

Chemical (Add rows as needed)	MW g/mol	Concentration Required for Demo	Amount Required for Demo	Amount of Chemical Needed for Preparation	Amount Recipe will Prepare
hydrogen peroxide (H_2O_2) CAS 7722-84-1	34.0	30% (~9 M)	150 mL	Buy at required concentration	N/A
potassium iodide (KI) CAS 7681-11-0	166	Solid (99+)	~10 g (scoop)	Buy at required concentration	N/A
Joy dish soap	-------	As purchased	~25 mL	Buy at required concentration	N/A
Food Coloring (Optional)	-------	As purchased	drops	Buy at required concentration	N/A

Demonstration Instructions with Associated Hazards & Controls

1. Don chemical splash goggles and nitrile gloves
2. Add ~150 mL of 30% H_2O_2 to the cylinder
   Hazards: splash, spill, sharps
   Controls: Ensure audience is back 10 feet; review spill response procedures prior to demo, wear eyewear and recommended gloves, ensure eyewash is functioning and available (alternate is eyewash solution in a bottle), clean up broken class using broom and dustpan, clean up small spill of concentrated hydrogen peroxide by diluting with water and wet paper towels – rinse thoroughly (no dry organic absorbents).
3. Add ~25 mL of dish soap to the cylinder and swirl to mix
4. Place cylinder on tray
5. If desired, add 4 drops of food color of choice at 4 points around the cylinder opening. Do not add to the H_2O_2/soap unless you want the "toothpaste" to be a uniform color rather than striped.
6. All at once add the scoopful of solid KI and swirl slightly.
   Hazards: splash, spill, dermal contact, heat, sharps, flammable gas
   Controls: Ensure audience is back 10 ft and do not allow observers to touch foam, review spill response procedures prior to demo, review ER for dermal contact of KI, continue to wear eyewear and gloves, have running water available, allow cylinder to cool prior to disposal, clean up broken glass using broom and dustpan, no open flames.

Waste Disposal
Unused reagents (if any) should be returned to storage.

This demo does not generate any hazardous waste that must be managed. Oxygen gas should be safely dispersed with proper ventilation and the remaining soap bubbles and KI solution may be flushed down the sink with water. Since local ordinances may vary, check with local water treatment/sewage authorities or the host institution to assure that this is appropriate.

General Information
Conflicting hazard information was found on the hazards of potassium iodide. Sigma Aldrich lists KI with an exclamation point and warning signal word. Fisher Scientific lists it as not requiring GHS elements. At VWR, I saw skull and crossbones for KI granules (product 74210) and none for KI (product # C6459, and exclamation point for a BDH product. Assume that it is a target organ hazard (fetus).

There are some known incompatibilities

☑ I have read the required information on the hazards of this demonstration and understand the risks to the demonstrator and audience

Signed:

Date:

Ventilation Requirements:

- ☐ hoods for preparation
- ☐ hoods for demonstration
- ☐ demonstration must be performed outside
- ☑ laboratory room ventilation

Emergency Equipment Requirements:

- ☐ standard lab ER equipment
- ☑ eyewash/shower
- ☑ spill kit

  running water
- ☐ fire extinguisher

Waste Requirements:

- ☐ labeled waste container(s) needed
- ☐ neutralize and dispose
- ☑ flush down drain with water

PPE Requirements (Demonstrator):

- ☑ gloves

  nitrile (all chemicals)
  Type
  Type
- ☑ eyewear

  chemical splash goggles (demonstrator)
  eyewear for audience (no)
- ☐ lab coat

  not required

Reactivity Precautions:

- ☐ flammable solvents
- ☑ corrosives
- ☑ oxidizers
- ☐ incompatible wastes

- ☑ Other (Flammable gas)

Prepare a Job Hazard Analysis (JHA) for the following task: ***Perform the Elephant's Toothpaste Demonstration***

The student will construct the JHA in the instructor provided template. All references to additional hazard information, Standard Operating Procedures, risk matrices or other supporting information to control hazards should also be included in the template or as attachments.

		Excellent (5 pts max)	Competent (3 pts max)	Needs Improvement (1 pt max)
General Required Information	Header Information	The JHA lists the job location, date, and person preparing the tool.	One of the required items is missing.	More than one of the required items is missing.
	Equipment & chemicals required	**Engineering Controls:** chemical fume hood, eyewash/shower unit; spill tray, safety shield, non-slip shoes **Equipment:** Beakers, large graduated cylinder, scoopula, **Chemicals:** 30% hydrogen peroxide, solid potassium iodide, distilled water, dish detergent, food color of choice **PPE Required:** chemical splash goggles, nitrile gloves, lab coat or apron. **ER:** spill equipment w/broom and dustpan, fire extinguisher	Eyewash/shower unit, spill tray, large graduated cylinder, storage bottle, 30% hydrogen peroxide, solid potassium iodide, water, chemical splash goggles, nitrile gloves, fire extinguisher	Graduated cylinder, hydrogen peroxide, potassium iodide, goggles, gloves
	Hazards Checklist	30% hydrogen peroxide is very corrosive to skin and eyes respiratory irritant. Potassium iodide dust is an inhalation hazard Physical hazard from oxidizing liquid, heat of reaction Flammable gas (O_2) produced Hazardous to environment	Mention of at least one health hazard (corrosive to skin or lungs) and at least one physical hazard (heat of reaction, oxidizing acid).	Mention of only health hazard

Steps	Adequate number of steps provided to accurately describe the task	5 – 8 unique, meaningful steps	3 – 5 unique steps	<3 steps
	Major steps identified	Obtain 30% hydrogen peroxide (H_2O_2) from storage and take to hood if available Obtain potassium iodide (KI) from storage Add ~150 mL of 30% H_2O_2 to the cylinder Add ~25 mL of dish soap and swirl cylinder to mix Add 4 drops of food color of choice at 4 points around the cylinder opening All at once add a small scoop of solid KI and swirl the cylinder slightly Clean up foam	Add ~150 mL of 30% H_2O_2 to the cylinder Add ~25 mL of dish soap and swirl cylinder to mix Add 4 drops of food color of choice at 4 points around the cylinder opening All at once add a small scoop of solid KI and swirl the cylinder slightly	Add ~150 mL of 30% H_2O_2, soap and 4 drops of food color to cylinder All at once add a small scoop of solid KI and swirl the cylinder slightly
PPE	Personal protective equipment and use well defined	Chemical splash goggles, gloves of best material (documented), lab coat or apron	Goggles, gloves (material not documented), and lab coat	Eye protection and gloves
Hazards	Significant hazards identified in the given steps	Dermal contact with potassium iodide Chemical splash – corrosion to eyes, skin, and lungs Flammable gas Chemical spill possible Oxidation hazard (incompatible with organic materials) Supporting material supplied with JHA (SDS, SOP, etc.) Sharps Thermal heat	Chemical splash/corrosive material Flammable gas Chemical spill possible Supporting material mentioned (e.g. See SDS for nitric acid) Heat	Chemical splash/corrosive material No supporting material Heat

Risk	Method of risk determination stated	Method given and risk stated quantitatively ***&*** qualitatively	Method given and risk stated qualitatively ***or*** quantitatively	No method given – stated qualitatively
	Risk description is appropriately assessed for step (not too high or too low)	Risk assignments are proportional to actual risk All steps of high risk are noted as high risk Low risk steps are recognized	Most high risk steps are identified Most low risk steps are recognized	High risk steps are not recognized Low risk steps are disproportionally assigned high risk values
Risk Control	Controls sufficient to lower risk	**Exposure Controls** **PPE:** Worker will don chemical splash goggles, nitrile gloves, and a lab coat or apron. **Engineering Controls:** Pour H_2O_2 in fume hood Use safety shield to protect audience **Administrative** Include and review SDSs as a control in this JHA. **ER Controls:** Spill kit w/ vermiculite and non-organic barrier materials Small broom & dustpan Review ER procedures & keep crowd back **Reactivity** H_2O_2 is very reactive - Ensure no organic materials or solvents in wash sink or containers to be used **Environmental/Waste** Concentrated H_2O_2 should not enter the environment. Small spills (<500 mL) can be contained and liberally diluted with copious amounts of water and cleaned up Do not use organic absorbents	**Exposure Controls** **PPE:** Worker wears goggles, gloves, and lab coat or apron. **Engineering Controls:** Laboratory ventilation **ER Controls:** Spill kit w/ neutralizing material Ensure no organic materials or solvents in wash sink **Environmental/Waste** No waste generated Dilute spills of H_2O_2 with copious amounts of water	**Exposure Controls** **PPE:** Worker wears goggles, gloves, and lab coat or apron. **Engineering Controls:** Laboratory ventilation **ER Controls:** Spill kit w/ neutralizing material

70% of the students will score an sum of at least 30 (competent) on their completed JHA assignment		
		Points
1	Header Information	
2	Equipment & chemicals required	
3	Hazards Checklist	
4	Adequate number of steps provided to accurately describe the task	
5	Major steps identified	
6	Personal protective equipment and use well defined	
7	Significant hazards identified in the given steps	
8	Method of risk determination stated	
9	Risk description is appropriately assessed for step (not too high or too low)	
10	Controls sufficient to lower risk	
	Total	

	Job Hazard Analysis – Elephant's Toothpaste **Job Location:** 318 GWH **Laboratory Group:** N/A **Date:** 07.01.17			
	Activity or Job	**Perform the Elephant's Toothpaste Demonstration**		
	Completed By	**Samuella Sigmann**		
	Equipment and Chemicals Required	**Chemicals:** 30% hydrogen peroxide (H_2O_2) CAS 7722-84-1; potassium iodide (KI) CAS 7681-11-0; Joy dish soap; food color (Optional) **Equipment:** 1 L graduated cylinder; spill tray, varies beakers, scoopula, **Emergency Equipment:** Fire extinguisher, eyewash/shower unit, spill kit, small broom & dustpan **PPE Required:** Standard lab dress and slip resistant shoes, chemical splash goggles, nitrile gloves, lab coat or apron **Engineering Controls:** safety shield, chemical fume hood (optional)		
Step	**Work Steps and Tasks**	**Hazards Identified for each Task / Step**	**Risk Level (exposure x probability x consequence) 1 – 10 scale**	**Control / Safe Work Procedures for each Task / Step**
1	Obtain 30% hydrogen peroxide (H_2O_2) from storage and take to hood if available		**Low (3)**	• Worker will don chemical splash goggles and nitrile gloves; lab coat or disposable apron. • 30% H_2O_2 is very reactive • Read SDS or literature for chemical hazards and ensure they are understood • Wear all PPE as above • Note location of and visually inspect spill kit w/ inert (nonorganic) neutralizing material • Review laboratory spill response and ER procedures • Use situational awareness while transporting to hood
2	Obtain potassium iodide (KI) from storage			• Use situational awareness while transporting to work area • If spilled, avoid inhalation of dust – collect with small broom and dustpan and dissolve in water
3	Add ~150 mL of 30% H_2O_2 to the cylinder	**Eye and dermal contact (corrosive)** **Respiratory irritant** **Chemical splash** **Spill** **Broken glass**	**Moderate (4)**	• Avoid inhalation. Do not allow in drains. • For small spill, dilute with water liberally prior to absorption with wet paper towels or absorbent pads. • Rinse all materials thoroughly prior to placing in the trash can. Broom & dustpan for glass • Work on spill tray • Pour H_2O_2 in chemical fume hood if available
4	Add ~25 mL of dish soap and swirl cylinder to mix	**Same as Step 1**	**Very low (0.5)**	• PPE from Step 1 • Broom & dustpan for glass • Work on spill tray
5	Add 4 drops of food color of choice at 4 points around the cylinder opening	**Same as Step 1**	**Very low (0.5)**	• Same as Step 2

6	All at once add a small scoop of solid KI and swirl the cylinder slightly	**Chemical splash – corrosive; eye damage; inhalation (KI dust)** **Chemical spill** **Flammability**	**Low (3)**	• Place cylinder on Reaction mixture will generate high temperature so do not let anyone handle the flask or play with the foam. • Place spill tray behind safety shield • Small amounts of solid KI can be swept up and dissolved in water and flushed down the drain (check with your EHS office) • Stay back 10 feet • Oxygen gas is generated – keep open flames away. (Include ignition of gas in the risk assessment if the nature of the gas will be included in the procedure) • Review fire extinguisher use
7	Clean up foam	**Dermal contact** **Thermal burn** **Slip hazard**	**Very low (1)**	• Allow reaction foam to cool and ensure reaction has stopped before cleaning • Use caution if the solution gets on the floor as mixture is slick. • No known hazardous waste generated; sudsy foam solution can be rinsed down the sink • Wear non-slip shoes
	Hazards Checklist:			
	Can someone be exposed to chemicals? **Yes**	If so, what is the nature of the chemical hazard? 30% hydrogen peroxide is a strong oxidizer. The concentrated form can cause blistering and discoloration of skin. Inhalation can cause respiratory edema. KI is a respiratory irritant and **SDS Reviewed?** **Yes**		
	Can someone slip, trip or fall? **Possible**	Can someone injure someone else? **Not likely**		
	Can someone be caught in anything? **Not likely**	Can someone strike against or make contact with any physical hazards? **Contact with oxidizing liquid** **Flammable gas is generated and could flash in a poorly ventilated room where fuel vapor of dusts are present**		
	Laboratory Supervisor or PI Comments – NEVER absorb concentrated hydrogen peroxide with organic material such as sawdust.[i] Avoid all organic materials.			
	Laboratory Supervisor or PI Signature			Date
	Employees Signature			Date

[i] Clark, D. E. 2001. "Peroxides and Peroxide-Forming Compounds." *Journal of Chemical Health and Safety*. 8(5): 12-21. (CAMEO Chemicals)

DRAFT

RAMP Safety Assessment Rubric for Chemical Demonstrations and Videos

Evaluation Scale	Problematic (up to 1 pt)	3 - Average (up to 3 pts)	Excellent (up to 5 pts)	Points awarded
Pedagogical Intent	Attention getting only: no science concept mentioned	Concept explained but student inquiry not encouraged	Student discussion of their obsercations and application of concept shown	
Safety education included	Injury or illness involved in video	Safety concerns described during video	Pre-demo safety info included	
Venue appropriateness	Workspace clearly not appropriate for chemistry performed	Some concerns about space arise during course of work	Space has appropriate equipment and layout for chemistry performed	
Audience appropriateness	Audience not age appropriate for this level of chemical hazard	Audience instructions appropriate to age group involved	Discussion of changes necessary for other audiences included	
Recognize Hazards	No information about chemicals used or process provided	Key chemicals identified, no safety information provided; No process hazards identified	Chemicals clearly identified with form, concentation, and amounts; process hazards described	
(Chemical hazards are identified by Globally Harmonized System requirements. Process hazards are changes in temperature, pressure or potential unplanned chemical reactions.)				
Assess Risks	No risk information provided	Selected risks mentioned and implictly prioritized	All chemical and process risks clearly described and prioritized	
(Assessing risks involves prioritizing scenarios in which the potential hazards are likely to cause damage and developing control strategies for those scenarios.)				
Manage Safety				
Ventilation	Ventilation concern arises in the course of the video (e.g. smoke obscures visibility)	Ventilation concerns implicitly addressed by equipment used	Ventilation requirements explcitly mentioned as part of the video	
Personal Protective Equipment for demonstator	No PPE or a problem results from demonstrator's PPE arises in the course of the video	Demonstrator's PPE appropriate for chemistry and worn correctly	Demonstrator's PPE appropriately used and explained	
Personal Protective Equipment for audience	Problem resulting from audience PPE arises in the course of the video	Audience PPE used appropriately	Audience PPE appropriately used and explained	
Planning by demonstrator	No evidence of planning - confused presenter throughout	Some confusion as demonstration proceeds	Presenter clearly in control and experienced with demonstration	
Instructions for audience	Audience injuries from lack of instruction	Audience participates in an orderly fashion; presenter understanding of risk implicit	NFPA 45 style briefing provided for audience	
Plan Protect				

Coordination of Plans with Host or Emergency Responders	Demonstrator or audience injuried without backup	Emergency plans possibly in place but unclear	Emergency plans explictly mentioned as part of discussion	
Appoint Safety Assistant	Demonstrator or audience injuried without assistance available	Safety assistant possibly present, but unclear	Training explicitly provided for safety assistant	
Fire Precautions	Unplanned fire	Fire safety possibly addressed, but unclear	Fire preparations explained	
Medical Emergency Precautions	Demonstrator or audience injuried without backup	Medical emergency possibly addressed, but unclear	Explictly mentioned as part of discussion and equipment on hand	
Hazmat Spill Precautions	Demonstrator or audience injuried due to spill or release	Hazmat preparations possibly addressed, but unclear	Explictly mentioned as part of discussion and spill equipment on hand	
Waste Disposal Practices	Environmental damage likely to result from waste disposal shown	Mentioned in passing	Clearly discussed	
Comments and other Observations:				
Point Total:				
Recommendation:	*Don’t use for safety reasons (don't do this anywhere)*	*Show video to start "safe science" discussion*	*Use as the basis for live demonstration*	