

Laboratory Safety

Laboratory safety involves the development of skills and responsibility and must be an integral part of every chemistry curriculum. This means that safety awareness must be integrated into each laboratory course including research with increasingly broader scope at more advanced levels. The creation of a culture of laboratory safety requires a broad commitment from all levels of the educational institution. At the department level, faculty need to assume responsibility for continuing review of safety issues with students in teaching and research laboratories, especially the persons responsible for undergraduate instruction, often graduate students or instructors. Faculty must lead by example in a coordinated departmental safety effort. At the administrative level, this will involve implementation of a chemical hygiene plan that is in agreement with any campus chemical hygiene/safety efforts and must address the safe handling, storage, and disposal of chemicals. Eye wash and showers must be in operating condition, and fume hoods with proper sashes are essential. Anyone working or visiting in the lab must be wearing goggles, and consumption of food or drinks must not be permitted. A clean, uncluttered laboratory is more likely to encourage careful work.

Development of safety skills may be divided into four emphasis areas.¹

- **Recognize Hazards**
- **Assess Risks**
- **Minimize Risks**
- **Prepare for Emergencies**

The ACS Committee on Chemical Safety has recently published three useful resources that provide guidelines for chemical safety in academic institutions,² and help in the identification and evaluation of hazards in research laboratories.³⁻⁴

Recognize Hazards

A hazard is a potential source of danger or harm and can result from working with chemicals, equipment, and instrumentation. Introduction to this topic can start with an understanding of the terms describing chemical hazards, such as “toxic”, “flammable”, or “corrosive”, and how to obtain information from chemical labels, Safety Data Sheets (SDS), and other reference sources. Chemical hazards encountered in early undergraduate laboratories should be explained in more detail – for example, acids, bases, flammables, and toxic compounds. At more advanced levels, more details of chemical and physical hazards should be explained so that students are able to identify hazards themselves in experiments – for example, types of toxic compounds, compressed gases, cryogenics, pressurized systems, peroxides, reactives, unstable compounds, pyrophorics, explosives, and water-reactives. Other topics might include toxicology, nanomaterials, biohazards, and radiological hazards, which become relevant when the chemistry curriculum becomes broader in scope.⁵

Assess Risks

Once a hazard(s) is recognized, laboratory safety necessarily requires an assessment or evaluation of risk from potential exposure to the hazard. Identifying potential routes of exposure is followed by judging the relative risk posed by the hazards of the experiment. The hazardous physical, chemical, and toxic properties of solvents, reactants, catalysts, products, and wastes should be considered as well as circumstances of the experiment – for example, how much is being used, is the right equipment available, can the hazard be controlled or minimized?

Are the reactions exothermic or water- or air-sensitive? Are there risks associated, for example, with the use of lasers or equipment utilizing high voltages (electrophoresis)?

Minimize Risks

Based on a risk assessment, experiments should be designed to minimize potential risks. These steps may involve carrying out experiments in a fume hood with a protective shield and wearing protective gloves and goggles. The handling and storage of wastes is a critical component. It is often useful to consider case histories of incidents that have resulted in injury or damage. What could have been done to prevent or minimize such incidents? Discussion can be implemented by giving students a picture of a risky or hazardous environment and then asking them, "What is wrong with this picture?"

Prepare for Emergencies

Since it is essential to react promptly and deliberately to emergencies, students should learn what to do in various emergencies and be prepared to act accordingly – for example, fires, injuries, and spills. Safety devices such as showers, eye washes, fire extinguishers, and spill kits, must be clearly labeled and their use and location known to all those working in a laboratory. Emergency phone numbers, alarms, and escape routes should be clear to everyone.

The Culture of Laboratory Safety

Faculty and staff must be leaders in safety: teaching safety to students, continuously promoting safety, demonstrating the importance of safety through their actions, and accepting responsibility for safety. At some institutions the graduate students teach the undergraduate labs, in which case the graduate students TAs must be champions of safety ethics. The Safety Ethic is, above all, a value, stated as: I value safety, work safely, prevent any risk-behavior, promote safety, and accept responsibility for safety.⁶⁻⁷ It emphasizes personal responsibility of each person involved. In order for this culture to thrive, everyone must be promoting it. It is, of course, necessary to be familiar with Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), Department of Transportation (DOT), and Department of Energy (DOE) regulations, but responsibility goes beyond simply complying with federal, state and local regulations – it is about caring for the safety of fellow students, faculty, and staff. There are several chemical and laboratory safety resources that can be very useful in building a strong culture of safety.⁸⁻¹¹

Curricular Approaches

Laboratory safety education and training is an ongoing process and therefore must be integrated into every laboratory course. In research laboratories, the responsibility for necessary instruction will lie with the research director. Because of time and resource constraints, presentation and discussion may be limited in lab lectures prior to the start of a laboratory or pre-lab assignments.

Three possible approaches are suggested:

1. A seminar course devoted entirely to laboratory safety;
2. Laboratory safety as part of a seminar devoted to chemistry as a profession; and,
3. Online materials where students would be required to do reading and then pass exams, the grades being recorded.

It is very important to emphasize that safety is about learning how to carry out laboratory work safely and not only about rules and regulations, so students are required to think about responsibility for safety in the conduct of their work. Working safely is a basic responsibility of every employee and every student. Reduce unnecessary risks,

insure that regulations are followed by others, and always bring safety concerns to the attention of a supervisor or a departmental safety committee. A departmental safety committee should be established if it does not exist.

References

1. Hill, Robert H, Jr. and David C. Finster, *Laboratory Safety for Chemistry Students*, Wiley, Hoboken, 2010. This is a comprehensive text that partitions safety considerations into three tiers, with increasingly more involved considerations being reflective of increased knowledge by students. Emphasis is on learning on a “need to know basis”.
2. *Guidelines for Chemical Laboratory Safety in Academic Institutions*, ACS Committee on Chemical Safety, Washington, DC., 2016. A comprehensive document providing a broad overview of the range of safety considerations for undergraduate, graduate and continuing safety education.
(www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/acs-safety-guidelines-academic.pdf?logActivity=true)
3. *Identifying and Evaluating Hazards in Research Laboratories*, ACS Committee on Chemical Safety, Washington, DC., 2015. A comprehensive overview of methodologies that can be used to assess and control hazards that can be successfully used in a research laboratory.
(www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/identifying-and-evaluating-hazards-in-research-laboratories.pdf)
4. *Hazard Assessment in Research Laboratories*, ACS Committee on Chemical Safety, Washington, DC. An on-line resource that helps with the identification of hazards, the assessment of risk, and selection of appropriate control measures to eliminate a hazard or reduce the risk of accident or injury.
(www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/acs-safety-guidelines-academic.pdf?logActivity=true)
5. *Prudent Practices in the Laboratory*, The National Academies Press, Washington, 2015. A comprehensive study of laboratory safety issues including leadership and management considerations.
(www.nap.edu/catalog.php?record_id=12654)
6. *Creating Safety Cultures in Academic Institutions: A Report of the Safety Culture Task Force of the ACS Committee on Chemical Safety*. A comprehensive document dealing with the promotion of safety culture across the entire educational institution.
(www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/academic-safety-culture-report-final-v2.pdf)
7. *Safe Science – Promoting a Culture of Safety in Academic Chemical Research*, National Academies Press, 2014. This document describes the culture of safety in research institutions and provides recommendations to support safety as a core value of these institutions.
8. *ACS Committee on Chemical Safety*, Washington DC. This ACS Committee serves as a resource to the ACS and the public on chemical and laboratory safety. It maintains current information on safety practices and recommendations, classroom safety, symposia, and safety-related activities.
(www.acs.org/content/acs/en/about/governance/committees/chemicalsafety.html)
9. *ACS Division of Chemical Health and Safety*, Washington, DC. This division organizes chemical health and safety symposia at National ACS meetings; publishes the *Journal of Chemical Health and Safety*, provides the DCHAS Listserve – an internet resource for division members providing a forum for questions and answers for chemical health and safety issues. (www.dchas.org/)
10. Safety Data Sheets (SDS) are required by the U.S. Occupational Safety and Health Administration under their Hazard Communication Standard. (www.osha.gov/Publications/OSHA3514.html)
11. *Chemical Laboratory Safety and Security: A Guide to Prudent Chemical Management*, L. Moran, T. Masciangioli (editors) An accompanying toolkit (7 components) is available for use with this manual.
(<http://dels.nas.edu/global/bcst/Chemical-Management>)

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