Laboratory safety for undergraduates

A short course in laboratory safety that consists of two 75-min sessions is described. All students enrolled in their first chemistry course are required to take the course and to take a brief quiz on the material. In every subsequent laboratory course in the curriculum, the student must make a satisfactory score on a safety test. The advantages and disadvantages of this approach to teaching laboratory safety are discussed.

By Joseph M. Crockett

BACKGROUND

Bridgewater College is a small, liberal arts school of about 1500 students located in the Shenandoah Valley of Virginia. The Chemistry Department has grown from a two-person department in 1995 to six faculty this fall. We graduate an average of five chemistry majors per year who have gone on to varied careers in chemistry. Most of our teaching responsibility concerns the freshman course (150 students last fall, mostly biology students), an introductory chemistry course (90 students last year), and two levels of organic chemistry (80 students last year). We are dealing with students who may be studying any of the academic areas on campus.

Over a period of about 25 years we have used several different methods of communicating safety to the students. Brief lectures on the first week of the laboratory and placing information in the laboratory manual for the students were two methods most commonly used. These efforts were implemented for many years but they were not sufficient to communicate the level of safety awareness that we desired. In 2004, we decided to start a specific class in laboratory safety. Our initial idea was to make a 1-credit class that would be required of every student taking our general chemistry or fundamental chemistry classes. This was not approved as a credit class so the material was partly condensed into a two part non-credit class that would cover the most important parts of the material. The class was scheduled at multiple times during the first weeks of the term and the students were required to take the entire class at the beginning of their first chemistry class. We assumed that the material would stick with the students and only required the one time attendance.

After 2 years we realized that the students were not always following the rules and had to be reminded too often to obey the safety rules or safety labeling. It was decided to expand the program to include repetitive study of the safety requirements. We then required all students who had previously taken the safety class to take a test at the beginning of every subsequent semester. The student has to pass the test with an 80% grade or retake the safety class.

If a student did not take the class, we put in a “two strike” policy. The first time the student misses the safety class, they receive a zero for their first laboratory grade. A second miss in a subsequent term will result in the student being dropped from that class and laboratory (our laboratory and lecture are joined for one grade). Each student who has missed once is notified at the beginning of the term to warn them of this second miss penalty. Since 2005, we have had 1136 students take the course and we have not had to dismiss any students from our classes.

Class Topics

The class covers several areas of safety education that we consider important for the students. In the first half of the class we discuss the fundamental areas of laboratory safety (chemical, personal, physical and group safety), governmental regulations, material safety data sheets (MSDSs) and safety terminology, and personal protective equipment. In the second half we discuss personal hygiene, handling of chemicals and glassware, first aid, labeling of chemicals (our system and other's), accidents, housekeeping, and the Chemical Hygiene Plan. The class takes faculty time in the preparation of notes and handouts for the lectures, preparation of tests and quizzes, grading, collection and separation of the signed dress codes, and informing students that they have completed the requirements or not. We initially did both parts of the class in one 3-hour period but, from student comments, we now split the two parts and schedule them at different times.

The two halves of the class are taught to groups of about 60–80 students at a time (180–200 students per term) using power point presentations to facilitate movement of the class and to keep on task. The students receive copies of the presentations to follow during the session along with a copy of general first aid instructions that are commonly found on MSDSs. These handouts are also available on-line for returning students who need to study for the test. The tests are different each term and we scramble the questions and answers to generate different forms.

Personal and Group Laboratory Safety

The idea that the students are part of a larger group and should be aware of the activities that occur in a laboratory is stressed in the course and several examples are given. We discuss with the students the different ways in which safety

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Material Safety Data Sheet information - for more complete information, contact the Chemical Safety Officer

**MSDS file #** | **Chemical** | **Propanol, 2-** | **Chemical First Aid.doc**
---|---|---|---
**First Aid Notes** | Do NOT induce vomiting if ingested. |  |  
**Fire fighting** | Water, CO2, dry powder, or foam |  | Highly flammable. Irritant to eyes. Toxic. Experimental teratogenic effects. Eye and skin irritant. Flammable  
**CAS number** | 67-63-0 |  | Bridgewater Safety Code: B - poison, R - flammable, Y - corrosive, G - carcinogenic, L - explosive, W - low  
**Storage Shelf** | 2 |  | BR(3)  
**Other CAS** |  |  |  
**MSDS Prep Date** | 11-05-2007 |  |  
**Solution Components** |  |  |  
**Synonyms** | Isopropyl alcohol, isopropanol, dimethylecarbinol |  |  
**Properties and Storage** |  |  |  
**Chemical Formula** | C3H8O |  |  
**Mol weight** | 60.06 |  |  
**Flash point, C** | 12 |  |  
**NFPA-Health-Flam-Reac-Special** | 2 - 3 - 0 |  |  
**Appearance** | Colorless liquid |  |  
**Special storage:** Store cool / dry and away from incompatible materials. Keep lid secure | Store under nitrogen |  |  
**Incompatibilities. If you have not used the chemical before, you should contact the Chemical Safety Officer for a more complete list.** | Oxidizing agents, acids, acid anhydrides, halogens, aluminum, alkali and alkaline earth metals, ammonia |  |  
**Health Effects** |  |  |  
**Target Organs** | Kidneys, nerves, cardiovascular, GI, liver |  |  
**Oral toxicity** | LDLO 3570 mg/kg human |  | National Toxicology Program  
**Inf Agency for Research on Cancer** | Group 3: Not classifiable as to carcinogenicity to humans |  |  
**Governmental Regulations, Listings, and Controls** |  |  |  
**DOT guideline** | Class 3, Flammable liquid |  |  
**OSHA Permissible Exposure Level** | 400 ppm/8 hr TWA |  |  
**SARA 313 (superfund)** | yes |  |  
**Toxic Substances Control Act listed** |  |  |  
**Clean Air Act** |  |  |  
**EPA Regulations** |  |  |  
**Clean Water Act** |  |  |  
**Registry of Toxic Effects of Chemical Substances (RTECS)** | NT8050000 |  |  
**National Toxicology Program** | Not listed - 10/15/2004 |  |  

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applies to the laboratory experience. They are introduced to chemical safety and the hazards that may be associated with the chemicals that we use in the laboratories; physical safety such as laboratory chairs, backpacks, laboratory carts, or anything else that is a barrier to mobility in the laboratory; personal safety relating to how a student behaves in the laboratory; and group safety. We discuss group safety with the students as it involves their awareness of others if any accident occurs in the lab or any instance occurs that forces the lab to be evacuated. A “buddy system” allows us to be certain that all have left the lab in the case of a chemical spill, fire, or other reasons.

The students are directed to notice all safety equipment upon entering the laboratories. This includes the safety exits and directions, locations of the fire extinguishers, the safety showers and eyewash fountains, the deluge hoses, the MSDS files, and the fume hoods. The students are made aware of the possibility of an accident and what we consider their proper response to be. In the event of any accident in a laboratory involving a major injury, all students are instructed to shut down their experiments (if feasible) and wait until told to continue. The professor determines the level of the injury and the immediate response. This can be simple first aid or other responses from lab evacuation or calling the rescue squad. In these latter instances, the cause of the accident is determined.

Attachment 2

Laboratory Dress Code Sign-off Sheet

Laboratory safety is of paramount importance. You will follow the rules listed below for appropriate dress in the laboratory.

Lab Dress Code:

- **Shoes, not sandals or open shoes**, are required in the lab at all times.
- Due to the probable spillage of water and the floor becoming slippery, rubber soled shoes, such as tennis shoes, are best.

- **Shorts or skirts will not be worn**. They will not keep solutions from splattering on your legs. Blue jeans may be the best type of lab wear.

- **Belly-button policy**: Shirts that expose your midriff are not permitted in lab. The bench top is near your waist level, so spills there will be common. A buttoned lab coat covering the midriff is acceptable.

- **Safety goggles are required at all times in the lab**.
- If you are wearing contact lenses in the lab, you must notify the instructor in case of an accident.
- Prescription glasses are acceptable with safety goggles.

Penalties:

- First violation - you will be sent back to your dormitory or house to make the necessary changes to come under compliance.
- Second violation - you will receive a zero for that lab.

I, ________________________________ (print) have read the laboratory dress code of the Bridgewater College Chemistry department. I agree to abide by rules of the Lab Dress Code. In the event that I come to lab improperly dressed, I understand the penalties as spelled above.

Signed: ___________________________ Date: ____________
by the faculty before the students resume their experiments.

GOVERNMENT REGULATIONS

One of the hardest parts of the class to teach is the introduction of federal regulations. When a student is not a science major they do not see the necessity of knowing about federal safety agencies. We introduce the agencies through some basic principles of each and relating them to non-scientific areas. We cite, as examples of other non-laboratory locations where the regulations apply, cleaning companies, photography studios, biological laboratories, schools, building contractors, athletic training rooms, and house painters. We find that the students can relate to these as many of them are art, psychology, business, or athletic training majors. We also introduce the community right-to-know provisions and topics such as Love Canal, Times Beach, and Erin Brockovich. The students are introduced to the Occupational Safety and Health Administration (OSHA) and the worker protection from chemical use, bloodborne pathogens (biology and neuropsychology laboratories), hazardous materials (the kiln in the art department), and other recognized hazards. We also talk about the Emergency Response Plan and our plans (in brief) in the case of an emergency such as fire, flood, earthquake, massive power outages, or chemical spills. Part of our discussion centers on the communities that are affected by these events. We discuss the Resource Conservation and Recovery Act (RCRA) dealing with waste minimization and land disposal of hazardous wastes and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) concerning the cleanup of abandoned or uncontrolled hazardous waste sites. The students are surprised to learn the number of cleanup sites across the country.

MSDSS

An updated MSDS is available to the student for all chemicals that are used in our laboratories. In each of our academic laboratories we keep a notebook of updated, complete MSDSSs for all of the chemicals that are used in the experiments for that laboratory. The file is maintained in case of an emergency so the MSDS will be at hand for rescue personnel. We also keep a short file of one-page MSDSSs (see Attachment 1) for each chemical used for a given experiment as it is performed in the laboratory. These files are replaced each week as the experiment changes. The one page forms give condensed information from the MSDSSs and other sources and are accessible from anywhere on our campus. We briefly discuss with the students the following information that is found on the MSDS and its importance.

(a) The date of preparation.
(b) The formula and molecular weight.
(c) The proper first aid to follow for contact by ingestion, skin contact, eye contact, and inhalation.
(d) Fire fighting.
(e) Storage requirements.
(f) Physical properties.
(g) Terminology.
(h) Government regulations.

Personal Protective Equipment

One of the most difficult points to force on a student is a dress code. Students routinely plead for us to relax the dress code on warm days. The reasons for specific dress are spelled out in the safety class. We thoroughly discuss clothing, eye protection, and foot protection and concisely state the reasons for each. We do not require lab coats, but have them available for the students who wish to purchase one. Jewelry is discouraged since chemicals can get trapped or react with rings. Gloves are available in the laboratory if desired by a student.

After we finish our discussion of personal protective equipment in the safety class, the students must write their name and sign the dress code (see Attachment 2). Failure to sign the code means that they did “not attend” the session, but they are still responsible for being properly dressed. The penalties for violation of the dress code are spelled out on the sheet that they sign and the signed sheets are kept in the laboratory. The first violation of the dress code will send the student back to their room to get properly dressed and they can return to finish the laboratory if they have time. A second violation is a zero for the laboratory experiment.

Personal Hygiene

A very common way to bring a potentially hazardous chemical in contact with other parts of the body is through

Attachment 3

Laboratory Clean-up.

- Clean all lab glassware that you have used and return it to the appropriate place in the lab.
- Return your lab tray to the cabinet.
- Rinse out and refill the burets with deionized water.
- Check the sinks for paper, glass, or plastic.
- Wipe down the benchtop with a wet paper towel.
- Put the chairs under the table (as possible).
- Leave the area as clean or cleaner than you found it.
Attachment 4

Chemical and Lab Safety Quiz. Name _______________________________________________ (print)

Pledged nondisclosure ________________________________________________ (signature)

_____ 1) Which of the following is considered improper lab dress?
   a- Tennis shoes
   b- A baseball cap
   c- A Bridgewater College t-shirt
   d- An exposed midriff

_____ 2) A teratogen causes
   a- cancer
   b- birth defects
   c- mutations

_____ 3) When you spill a strong acid on the body, the first step is
   a- remove contaminated clothing
   b- flush with water.
   c- neutralize the acid with a weak soda
   d- neutralize the acid with a strong base

_____ 4) When entering a lab for the first time, you should note the location of all the following EXCEPT
   a- your chair
   b- safety showers
   c- fire extinguishers
   d- the MSDS’s

_____ 5) If you want to find an MSDS, you would NOT look
   a- in Dr. Crockett’s office
   b- in the MSDS notebook on the lab shelf
   c- in the stockroom
   d- in the yellow folder in the MSDS basket

_____ 6) In our labs, when a bottle of chemicals has a yellow dot on it, the chemical is
   a- Flammable
   b- Toxic
   c- Corrosive
   d- Carcinogenic

_____ 7) The letters OSHA stand for
   a- Occupational Safety and Hazard Assistance
   b- Our national Study of Hazards and Accidents
   c- Occupational Safety and Health Administration

_____ 8) A strong oxidizer will behave as
   a- a corrosive
   b- an acid
   c- a base
   d- a carcinogen

_____ 9) The fire (emergency) exit from the lab is posted
   a- on the back of the room door
   b- at the MSDS basket
   c- in the stockroom
   d- next to the door

_____ 10) When finished with the lab on a given day, the one thing you do not need to do is
    a- remove your safety goggles
    b- wipe down the benchtop
    c- clean all glassware
    d- leave the area clean

_____ 11) If you are not properly attired for the lab, on which violation will you first receive a zero for the lab.
    a- second
    b- third
    c- first
    d- fourth
demonstrated to the group. The hand-label twice before pouring the chemical.

b) cover the label with your hand so any drips do not destroy the label
c) the glass stopper is placed on the benchtop
d) reading the bottle label once is sufficient

A lachrymator is
a- a substance that causes you to cry
b- a carcinogen
c- a compound that makes you sneeze
d- a toxin

In our labs, when a bottle of chemicals has a red dot on it, the chemical is
a- Toxic
b- Corrosive
c- Carcinogenic
d- Flammable

During a lab, where do you NOT go to get an accident report form?
- in Dr. Crockett’s office
- in the secretary’s office
- in your professor’s office
- in the chemistry stockroom

the hands. Students will commonly wipe their foreheads on hot days, scratch parts of their faces, write in their notebooks and then hold the pen in their mouth or behind their ears, go to the bathroom during laboratory time, or finish laboratory and go to dinner—all without washing their hands. When we demonstrate these problems to the students, they find it funny until it happens to them.

We stress the need for students to wash their hands often during the laboratory and before they leave for any reason. We provide soap and paper towels at the major sinks in each laboratory.

Handling Glassware, Chemicals, and Used Chemicals
One common injury that occurs in the laboratory is the improper handling of hot glassware or chemicals. We demonstrate the proper handling of beakers, flasks, and crucibles when they are hot. We show the types of tongs that are available in the laboratory and demonstrate the type that works best for each type of heated laboratory ware.

The proper handling of a chemical bottle is shown for both a common bottle with a screw top and an acid bottle with a standard taper stopper. The students are instructed to read the label twice before pouring the chemical. The handling of both types of bottles is demonstrated to the group. The handling of waste chemicals is also discussed with the students, stressing the necessity to not mix incompatible wastes.

First Aid
We only cover basic first aid in the safety course. The most common injuries that we see in our laboratories are chemical contact, cuts, and burns. The students are instructed to first flush any injury with water (unless instructed otherwise in the pre-laboratory presentation) and call for the professor. We have safety showers, eyewash fountains, and bench top deluge hoses at multiple sites in every chemistry laboratory. After examination of the affected area we either apply simple first aid or call the local rescue squad for transportation to the campus nurse, college physician, or the local hospital. In 25 years we have only had three incidents where it was necessary to take a student from the campus for an injury in a chemistry laboratory.

Chemical Labeling
We have developed a simple labeling system based on the National Fire Protection Association (NFPA) diamond that we use on primary and secondary containers and introduce the student to the NFPA system. We have taken the data that we are able to gather from all sources such as the NFPA, the Global Hazard System (GHS), and the International Agency for Research on Cancer (IARC). Our system uses the NFPA colors to indicate toxicity (blue), flammability (red), and reactivity (yellow) and stress the relationship between the systems. The labels on various bottles are shown to the students to make them aware of the labeling system. The storage of chemicals and removal from the stockrooms are not discussed until the student’s sophomore year in the major laboratory for organic chemistry.

Accidents and Fire Exits
The students are shown the positions of fire equipment and the emergency exits from the laboratories and the building. All exits are marked with picture and word next to the inside of the laboratory door.

All accidents are reported to the department chair and a specific form is provided in the MSDS basket in all of the laboratories. The follow-up procedure of examining the cause of the accident and working to prevent such an accident in the future is discussed with the students during the safety course. We briefly discuss the possibility of a change in the laboratory procedure, a change in the chemicals used in the laboratory, or a change in the student attitude (an accident caused by sloppy work).

Housekeeping
The laboratory spaces at Bridgewater College are used by many laboratories for the course of a week. Our laboratories are used every day and need to be ready for each subsequent laboratory. We remind students that the laboratory at the end of the day needs to be as clean as or cleaner than it was when they arrived. We have a check-list (see Attachment 3) for students at the end of the laboratory that concerns cleaning of glassware, handling of used chemicals, trash, and cleaning the bench tops.

CHEMICAL HYGIENE PLAN
The Chemical Hygiene Plan is kept online and the students are told how to access the plan and given some basics about the plan. We briefly discuss the plan as it involves movement, handling, and labeling of chemicals on our campus. We tell the students that the plan
Attachment 5

Department of Chemistry Safety Exam. Spring, 2009. Name (print) ________________________________

This test is pledged non-disclosure. I have not discussed the contents of this test with another student prior to taking the test. Name (signed) ________________________________

____ 1) In the NFPA diamond the color blue refers to a compound’s
   a- toxicity
   b- carcinogenicity
   c- flammability
   d- water reactivity

____ 2) In our labs, when a bottle of chemicals has a red dot on it, the chemical is
   a- Toxic
   b- Corrosive
   c- Carcinogenic
   d- Flammable

____ 3) When we label a compound with a large green dot, the chemical is
   a- toxic
   b- combustible
   c- carcinogenic
   d- water reactive

____ 4) The proper disposal of paper is
   a- in the stone crock on the laboratory bench
   b- in the broken glass box
   c- in the trashcan
   d- in the sink

____ 5) ALL fire escapes from the third floor will involve
   a- turning left and heading for the stairs
   b- exiting the building and remaining together as a class
   c- opening the nearest window and exiting to the roof of the second floor
   d- going down the steps to the first floor and exiting to the rear of the building

____ 6) The proper disposal of broken glass is
   a- in the broken glass box in the lab
   b- there is no one proper way to dispose of broken glass
   c- in the sink
   d- in the trashcan

____ 7) When entering a lab for the first time, you should note the location of all the following EXCEPT
   a- safety showers
   b- fire extinguishers
   c- your chair
   d- the MSDS’s

____ 8) The MSDS will contain all of the following information except
   a- what to do when the compound is spilled on the skin
   b- a drawing of the molecule
   c- the date that the MSDS was written
   d- how to put out a fire

____ 9) When pouring from a bottle
   a) do not cover the label with your hand so you can read the label
   b) the glass stopper is placed on the benchtop
   c) reading the bottle label once is sufficient
   d) cover the label with your hand so any drips do not destroy the label

____ 10) The fire (emergency) exit from the lab is posted
   a- on the back of the room door
   b- in the stockroom
   c- next to the door
   d- at the MSDS basket
11) During a lab, where do you NOT go to get an accident report form?
   a- in Dr. Crockett’s office
   b- in the secretary’s office
   c- in your professor’s office
   d- in the chemistry stockroom

12) OSHA is responsible for
   a- cleanup of large chemical spills
   b- worker protection from chemical use.
   c- labeling trucks carrying hazardous substances
   d- community response

13) The mandatory document that sets the safety guidelines for handling chemicals at BC is called the
   a- Eagle
   b- MSDS
   c- Chemical Hygiene Plan
   d- college catalog

14) The Right to Know provision about the presence of hazardous chemicals in the community is part of
   a- SARA (Superfund Amendments and Reauthorization Act)
   b- CERCLA (Comprehensive Environmental Response. Compensation and Liability Act)
   c- TSCA (Toxic Substances control Act)
   d- RCRA – Resource Conservation and Recovery Act

15) The cleanup of hazardous waste sites is part of
   a- SARA (Superfund Amendments and Reauthorization Act)
   b- CERCLA (Comprehensive Environmental Response. Compensation and Liability Act)
   c- TSCA (Toxic Substances control Act)
   d- RCRA – Resource Conservation and Recovery Act

16) A species is labeled as a lachrymator. The compound
   a- will be a skin irritant
   b- will have a sweet taste
   c- will cause sneezing
   d- will irritate the eyes.

17) A species which will cause birth defects is called a
   a- poison
   b- carcinogen
   c- mutagen
   d- teratogen

18) A strong oxidizer will also behave as
   a- an acid
   b- a base
   c- a corrosive compound.
   d- a carcinogen

19) The LDLo for a compound is given as 245 mg/kg for rats. The term LD50 refers to
   a- one-half the dose that will kill all of the rats.
   b- the dose that can kill all rats
   c- the lowest dose that can a rat.
   d- the dose that will kill most rats

20) If you are not properly attired for the lab, on which violation will you first receive a first zero for the lab.
   a- first
   b- second
   c- third
   d- fourth

21) Which of the following is not proper dress for the laboratory?
   a- a lab coat
   b- an exposed midriff
   c- jeans
   d- a short sleeve shirt
will be discussed in more detail in the chemistry major organic laboratory.

**THE SAFETY TEST**

We give two types of safety tests to the students. At the conclusion of the second part of the safety class we give a short test (see Attachment 4) that the students take using the notes which they have taken during the safety class. The purposes of this specific test are for us to look at points where our presentation could be confusing and to take attendance during the second part. The grades on this test are not recorded since it is an open note quiz.

The primary safety test (see Attachment 5) is comprised of thirty questions (multiple choice) from the information on the class. This is the test is given at the beginning of each semester to students taking a second or
subsequent chemistry class. We schedule multiple times at the beginning of each term and the test takes about fifteen minutes. Each returning student who does not pass the test or misses the test must repeat the safety class. If a student repeats a class due to a low grade, we require them to repeat the safety class as well.

The repetition of the safety class when the test is not passed is one of the strengths of our course. Many students do not learn material from a traditional class the first time and this is true for the safety class. As time has progressed the average test score has increased to 23 (77%) this past year and the percentage of students that pass the test has also increased to 45%.

**SUMMARY**

Safety is one area where we in academia have all been lax in enforcement over many years. When we fail to do our job sufficiently, we jeopardize our students, our staff, and ourselves. Having tried other systems and not seeing the results we wanted, we feel that this program of presentation, testing, and repetition is working. Our program also has the growth factor to allow for changes as other topics present themselves. We can discuss any topic that is discussed on our DCHAS threads, or may be in other news media. We constantly reexamine the program yearly and make changes as needed. We believe that this program, although still developing, is a giant leap from where we were. Our goals are to continue its development and make all of our laboratories safer for our students. The major disadvantage to our system is the time commitment of the faculty conducting the sessions, preparing the materials, grading the quizzes and tests, and handling the program during the term.

Since we have initiated and modified our program, we have seen an increase in the awareness of safety regulations. Students rarely show up for a laboratory improperly dressed and if they do, they know that no exception will be granted. They will ask about the specific toxicity or flammability of a chemical in use, and they become uncomfortable if they are not wearing proper eye protection. They are aware that the program is in place to protect them and their fellow students, that it is place for all students (from non-science majors to senior chemistry majors in research laboratories), and that it is place for all faculty and staff.

**FURTHER READING**


Young, J. A. Improving Safety in the Chemical Laboratory; John Wiley and Sons; New York, NY, 1987.


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1 As this program has been developed, we have used different resources for compiling the information. The following references are the primary sources that have been used. We do not have a complete list from the varied html files and books that have been used. The following is a list of the books and websites that I have used the most.