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Appendices

Appendix A: Laboratory Standard (29 CFR 1910.1450)
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1.0 INTRODUCTION

1.1 Purpose and Authority

The purpose of the Chemical Hygiene Plan (CHP; the Plan) is to protect employees from physical and health hazards associated with occupational exposure to chemicals in the laboratory, and to maintain occupational exposures below recommended levels. The components of the Plan include:

- establishing laboratory safety rules and standard operating procedures;
- defining criteria for exposure control measures, including personal protective equipment, engineering controls, and safe work practices;
- conducting an ongoing ventilation inspection and maintenance program;
- providing information and training to employees regarding the provisions of the Plan, and the identified hazards of chemicals in their work area;
- defining criteria for laboratory activities that would require prior approval;
- conducting environmental and personnel monitoring to continually re-evaluate hazards, and making provisions for medical consultations and examinations to assess potential exposures;
- designating responsibilities for implementation of the Plan, including the Chemical Hygiene Officer and Committee members; and
- making provisions for additional exposure protection for extremely hazardous substances.

The CHP has been developed in compliance with OSHA 29 CFR 1910.1450, “Occupational Exposures to Hazardous Chemicals in the Laboratory”, better known as the “Laboratory Standard” (LS), effective January 31, 1991; a copy of the standard is attached as Appendix A.

1.2 Scope and Application of the Standard

The LS applies to all employers engaged in the laboratory use of hazardous chemicals, as defined by the standard, and to all employees engaged in laboratory work that may expose them to hazardous chemicals.

For these purposes, the LS supersedes all other parts of the more general standards of 29 CFR 1910 Subpart Z (“Toxic and Hazardous Substances”), except that: (1) permissible exposure limits (PELs) shall be observed; (2) OSHA mandated prohibitions on eye and skin contact for specific substances shall be observed; and (3) where the action level or PEL is routinely exceeded for an OSHA regulated substance with monitoring and medical surveillance requirements, the monitoring and medical surveillance requirements of the standard regulating that substance will apply.

The LS does not apply to activities which do not fit the definition of laboratory use (see Section 2.1), or provide no potential for employee exposure.

1.3 General Principles

Bowdoin College is dedicated to the safe operation of their laboratories, and adopts the following guiding principles in the implementation of the CHP:

- Minimization of chemical exposures to the extent possible;
- Avoidance of the underestimation of risks associated with chemical exposure;
- Providing adequate ventilation and other operational controls;
- Developing and continuously re-evaluating its Chemical Hygiene program; and
- Complying with the PELs and threshold limits values (TLVs) associated with the hazardous chemicals used in the workplace.
2.0 RESPONSIBILITIES WITHIN BOWDOIN COLLEGE

2.1 President and the Board of Trustees

The President and the Board of Trustees are responsible, with other administrators, for the funding of Bowdoin College’s policies related to Laboratory Safety at all facilities and properties under campus control.

2.2 Department Chairs

Department Chairs are responsible for regular communication with department personnel regarding lab safety policies relevant to department operations, including the requirement for current training for all lab personnel. Items such as hood certification, inspection of lab safety equipment such as showers, eye washes and fire extinguishers are provided by the College. The Department Chair appoints a department member to serve on the Chemical Hygiene Committee.

2.3 Principal Investigator/Laboratory Supervisor

The day-to-day responsibility for the implementation of laboratory safety and adherence to safe laboratory practices rests with the PI/Laboratory Supervisor or Laboratory Instructor (see 2.4) within individual laboratory units. All personnel, including PI/Laboratory Supervisors, Laboratory Instructors, employees, and students, have a duty to fulfill their obligations with respect to maintaining a safe work environment.

Specific duties and responsibilities are presented below for personnel who work in areas where potentially hazardous chemicals or equipment are present. All faculty, staff, other employees and other personnel working with potentially hazardous chemicals or equipment have the responsibility to conscientiously participate in training seminars on general laboratory safety (and any other training required for work in a particular lab), and review and be familiar with the contents of the CHP. Students who are undertaking a laboratory independent study or Honors project who are not paid (or are otherwise not technically employed by the College) have the same training requirements and responsibilities as employees performing equivalent work. Those working with or around chemicals are responsible for staying informed about the chemicals in their work areas, safe work practices and proper personal protective equipment (PPE) required for the safe performance of their job. Failure to comply with these requirements may result in suspension of laboratory activities until corrective action is implemented.

The PI/Laboratory Supervisor has responsibility for the health and safety of all personnel working in his or her laboratory. Perhaps the most important aspect is the responsibility of the PI/Laboratory Instructor to set a good example by following all the safe procedures all the time (attitude, clothing, PPE, training, procedures). The PI/Laboratory Supervisor may delegate safety duties, but remains responsible for ensuring that delegated safety duties are adequately performed. The PI/Laboratory Supervisor is responsible for:

1. Knowing all applicable health and safety rules and regulations, training and reporting requirements and standard operating procedures associated with laboratory safety for their lab operations.

2. Ensuring that personnel (including self) have current training as appropriate in Laboratory Safety, Biomedical Waste, Animal Care and Use, Sharps, Hazardous Waste, Radiation (Radioactivity and Lasers), Bloodborne Pathogens before they begin work. Establish what additional training is necessary for their lab operations. Document their own expertise in these operations (currently Chair of Chemical Hygiene Committee archives training documentation).

3. Identifying hazardous conditions or operations in the laboratory or other facility containing hazardous chemicals or equipment, determining safe procedures and controls, and implementing and enforcing standard safety procedures (Hazard Assessment).

4. Using standard operating procedures (SOP) and performing literature searches relevant to health and safety for laboratory-specific work. Generating written SOP if not otherwise available. These SOPs are to be used as the basis for Laboratory Specific Training.
5. Requiring and providing prior-approval for the use of hazardous chemicals and apparatus in the PI/Laboratory Supervisor’s laboratory or other facility.

6. Consulting with EH&S and/or Chemical Hygiene Committee on use of higher risk materials, such as use of particularly hazardous substances* or conduction of higher risk experimental procedures, so that special safety precautions may be taken.

7. Maintaining an updated chemical inventory for the laboratory or facility (stockroom inventory is sufficient).

8. Ensuring laboratory or other personnel under his/her supervision have access to and are familiar with the appropriate safety manual(s) and safety information (SDS, SOPs, etc.).

9. Training all laboratory or other personnel he/she supervises to work safely with hazardous materials and equipment, and maintaining written records of laboratory-specific or other specialized training (Laboratory-Specific Training Form). Electronic records of training are encouraged. Training must include information of the location and availability of hazard information and SOPs to be used in the lab.

10. Actively monitoring workplace engineering controls (e.g., fume hoods) and safety equipment (e.g., emergency showers/eyewashes, fire extinguishers, other safety equipment etc.) to establish that they are operating properly. Promptly notifying EH&S and/or Facilities Management should he/she become aware that any of these are not operating properly. Hazardous operations must cease until the problem is corrected.

11. Ensuring the availability of all appropriate personal protective equipment (PPE) (e.g., laboratory coats, gloves, eye protection, etc.) and ensuring the PPE is maintained in working order and in use.

12. Ensuring that equipment peculiar to the lab is properly maintained and inspected (autoclave, scintillation counter, etc.).

13. Conducting periodic self-inspections of laboratory or facility and maintaining records of inspections, as required.

14. Promptly reporting of accidents and injuries to EH&S. All injuries MUST be reported to EH&S and Security (x3500).

15. Informing facilities personnel, other non-laboratory personnel and any outside contractors of potential laboratory-related hazards when they are required to work in the laboratory environment.

16. Identifying and minimizing potential hazards to provide a safe environment for repairs and renovations.

*particularly hazardous substances are defined as reproductive toxins, acutely toxic substances and select carcinogens, which include regulated carcinogens, and radioactive materials.

2.4 LABORATORY INSTRUCTORS AND OTHER LABORATORY PERSONNEL

1. Obtains, and keeps current, training on all applicable College laboratory safety policies.

2. Reads, understands, and follows all safety rules and regulations that apply to the work area.

3. Seeks advice and approval regarding planned hazardous operations.

4. Plans and conducts each operation, laboratory class, or research project in accordance with all applicable College laboratory safety policies.

5. Promotes good housekeeping practices in the laboratory or work area.

6. In instructional labs: The Lab Instructor communicates appropriate portions of the CHP to assistants and
students in the work area, including information on hazards of operations and appropriate clothing and PPE use. Ensures that lab assistants attend Lab Safety Awareness training.

7. Notifies the PI/Lab Supervisor/Dept Chair of any hazardous conditions or unsafe work practices in the work area.

8. Uses PPE as appropriate for each procedure that involves hazardous chemicals or apparatus.

9. Immediately reports any job-related illness or injury to the lab supervisor and to Security (x3500).

2.5 The **Laboratory Manager coordinates** the procurement, storage, distribution, and disposal of chemicals; and the purchasing and distribution of PPE and laboratory supplies and apparatus, for the Science Center.

Each **Employee** working with or around chemicals, having been informed and trained, is responsible for remaining aware of and handling those chemicals safely, according to the associated hazards and in observance of hygienic work practices. If uncertainty arises as to the hazards of a substance or the safety of a procedure, it is the responsibility of the employee(s) involved to ask for guidance.

2.6 **Chemical Hygiene Officer**

The default Chemical Hygiene Officer (CHO) at Bowdoin College is the Manager of Environmental Health and Safety (EHS). The CHO: (1) coordinates with the Chemical Hygiene Committee to develop and implement appropriate chemical hygiene policies and practices; (2) works with the Laboratory Supervisors to assess safety precautions and maintain adequate facilities; (3) advises the Laboratory Manager on the use and disposal of chemicals; (4) knows the current legal requirements regarding regulated chemicals; and (5) seeks ways to improve the Chemical Hygiene Plan.

2.7 **Chemical Hygiene Committee**

The Chemical Hygiene Committee (CHC) is composed of the Chemical Hygiene Officer, plus one or more representatives of each of the affected departments, as listed in *Appendix B*. The CHC meets at least annually to review the CHP.
3.0 DEFINITIONS

3.1 Regulatory

GHS – Globally Harmonized System of Classification and Labeling of Chemicals – new system adopted by OSHA, scheduled for full implementation by June 1, 2016. Revises hazard communication on labels and in (Material) Safety Data Sheets.

Hazardous chemical means 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; that is, a chemical to which exposure above a certain level constitutes a health hazard.

Health hazards include chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins (including teratogens and mutagens), irritants, corrosives, sensitizers, hepatotoxins (liver), nephrotoxins (kidney), neurotoxins, agents which act on the hematopoietic systems (bone marrow and lymph), and agents which damage the lungs, skin, eyes, or mucous membranes. Appendices A, B of the OSHA “Hazard Communication Standard” (HCS; 29 CFR 1910.1200) provide further guidance in defining the scope of health hazards, and determining whether or not a chemical is to be considered hazardous for the purposes of this standard.

Physical hazard means a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water reactive.

Laboratory means 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.

Laboratory scale means work with substances in which the containers used for reactions, transfers and other handling are designed to be easily and safely manipulated by one person. Laboratory scale excludes work places whose function is to produce commercial quantities of materials.

Laboratory use of hazardous chemicals means handling or use of such chemicals in which all of the following conditions are met: (1) chemical manipulations are carried out on a laboratory scale; (2) multiple chemical procedures or chemicals are used; (3) the procedures involved are not part of a production process, nor in any way simulate a production process; and (4) “protective laboratory practices and equipment” are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

Protective laboratory practices and equipment means those laboratory procedures, practices and equipment accepted by laboratory health and safety experts as effective, or that the employer can show to be effective, in minimizing the potential for employee exposure to hazardous chemicals.

SDS – Safety Data Sheet – A compilation of physical, chemical, medical and regulatory data for a specific chemical.

3.2 Chemical/Physical

Particularly hazardous substance are those which fall in any of the following categories: select carcinogen, reproductive toxin, or substances which have high acute toxicity. See Select Carcinogen, Chemicals of high chronic toxicity, and Highly toxic chemicals below and Sections 6.2 and 6.3.

Acute chemical hazards are those which fall in any of the following categories: corrosives, irritants, sensitizers, toxic chemicals, highly toxic chemicals, embryotoxins, and agents which affect the following target organs: (1) blood; (2) skin; (3) eyes; or (4) central nervous system (narcosis, behavioral changes, decrease in motor function).

Highly toxic chemicals are those with LD$_{50}$ of < 300 mg/kg (oral) or < 1000 mg/kg (dermal) or LC$_{50}$ in air of < 2500 ppm (gases) or < 10 mg/L (vapor) or < 1 mg/L (mist, fume, dust). See Section 6.3.
Toxic chemicals are those with LD₅₀ of 300-2000 mg/kg (oral) or 1000-2000 mg/kg (dermal), or LC₅₀ of 2500 - 5000 ppm (gases) or 10-20 mg/L 200-2,000 ppm (vapor) or 1-5 mg/L (mist, fume, dust).

Chemicals of high chronic toxicity include carcinogens, and/or agents which affect the following target organs: (1) hematopoietic system (bone marrow and lymph); (2) lungs; (3) liver; (4) kidneys; (5) central nervous system (loss of motor coordination, palsy, behavioral changes, degeneration of mental capacity); or (6) reproductive system (teratogen, mutagen, or agent causing significant reduction in fertility). See Section 6.3.

Select Carcinogen - A chemical is a select carcinogen if it is: (1) regulated by OSHA as a carcinogen; or (2) listed as known to be a carcinogen by NTP (National Toxicology Program, latest edition); or (3) IARC Group I (carcinogenic to humans); or (4) IARC Group 2A or 2B (reasonably anticipated to be carcinogens).

Flammable - chemicals with a flash point below 100 °F (38°C).

Combustible - chemicals with flashpoints between 100 and 200 °F (38-93°C).

Reactive - chemicals which meet any of the following criteria:

- Ranked by GHS as
  - Oxidizer
  - Explosive
  - Self-reactive
  - Pyrophoric
  - Self-heating
  - Substances which on Contact with Water Emit Flammable Gases
  - Organic Peroxide
- Ranked by NFPA as 3 or 4 for reactivity.
- Determined by DOT to be any of the following:
  - Oxidizer
  - Organic peroxide
  - Explosive (Class A, B or C)
  - Pyrophoric
  - Fits the USEPA definition of reactive in 40 CFR 261 (water-reactive; forms explosive mixtures with water or generates toxic fumes when mixed with water; contains cyanide or sulfide soluble at pH 2-12.5; capable of detonation or explosion at standard temperature and pressure or on heating under confinement)
  - Fits the OSHA definitions of unstable, polymerizable, self-reactive, or self-heating
  - Is found to be reactive with ordinary substances (air-reactive, water-reactive, pyrophoric)

Contact hazard - a chemical meeting any of the following criteria - corrosive, irritant, sensitizer, toxic, highly toxic, lachrymator or oxidizer.

Corrosive - a chemical which meets any of the following criteria:

- OSHA (29 CFR) - causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact.
- DOT (49 CFR Part 173 Appendix A) - destroys or changes irreversibly the structure of the tissue of intact skin of albino rabbits at the site of contact following an exposure period of four hours.
- EPA (40 CFR) - pH < 2 or pH > 12.5, or liquid and meets a specified steel corrosion test specified in 40 CFR 261.22 (a) (2).

The boiling point is when the vapor pressure of the vapor over a liquid is equal to the pressure of the surroundings (usually very close to one atmosphere or 760 Torr unless in a closed system). Substances with boiling points only slightly above room temperature have high vapor pressures at room temperature.
The *flash point* of a substance is the temperature at which a liquid gives off vapor in sufficient concentration to form a mixture with air near the surface of the mixture which can be ignited by an external flame.

The *ignition temperature* of a substance, whether solid, liquid or gas, is the minimum temperature required to cause self-sustained combustion independent of the heat source and with no external flame (steam pipe, incandescent light bulb, hot plate, heating mantle, etc.). When a substance reaches the ignition temperature, spontaneous ignition occurs. The two most commonly used solvents with relatively low ignition temperatures are carbon disulfide (80°C) and diethyl ether (160°C).

*Upper and lower flammable (explosive) limits* are the upper and lower concentrations (percent by volume) of vapor in air between which a flame is propagated when an ignition source (flame, spark) is present. Below the lower limit, the mixture is too lean to burn, above the upper limit, the mixture is too rich to burn. The range widens with increasing temperature and in oxygen-rich atmospheres. In practice, when a solvent is spilled or heated or allowed to vaporize in the presence of an ignition source, the lower limit is quickly reached and ignition occurs before the upper limit is reached.

### 3.3 Health and Exposure

**TLV (Threshold Limit Value)** - Time-weighted average concentration for a normal 8-hour workday to which nearly all healthy workers may be repeatedly exposed without adverse effect.

**PEL (Permissible Exposure Level)** - For a select set of chemicals, a PEL is the airborne concentration of a chemical to which healthy workers can be exposed for 8 hr/day for entire working career with no ill health effects. This information is found in Section 8 of the SDS. The complete tables of PEL’s can be found at [www.osha.gov](http://www.osha.gov), search for 1910.1000 Table Z-1 and Z-2.

**STEL (Short Term Exposure Limit)** - Maximum concentration to which healthy workers can be exposed for periods up to 15 min. Such exposure should be limited to no more than four per day with periods of at least 60 min each between exposures; the total time-weighted exposure per day should not exceed the TLV value.

**LD$_{50}$** - lethal dose 50 - the minimum single dose of a chemical that causes the death of 50% of an animal population from exposure to the substance by any route other than inhalation. See the “SDS Pocket-Dictionary” for more information on these units, as well as LC$_{50}$, LDLo and LCLo.
4.0 LABORATORY FACILITIES

4.1 Facility Design and Usage

Each laboratory area will be equipped with: (1) adequate general ventilation and vented hoods; (2) chemical-resistant surfaces and sinks; (3) provisions for hazardous materials and waste collection (as dictated by current use); (4) required safety equipment (including emergency shower, eyewash station, first aid kit, fire extinguisher, telephone with emergency numbers, and fire alarm); and (5) emergency information, including a hazard communication (SDS) station, appropriate signage, egress maps, and contact lists. The work being conducted and its scale will be appropriate to the facilities available and the ventilation capacity.

4.2 Ventilation

Ventilation for each laboratory space will: (1) supply both adequate breathing air and input for local ventilation devices (i.e., vented storage cabinets, canopy hoods, and snorkels); (2) provide 4-12 positive changes of air per hour, to direct air flow from the laboratory to the exterior of the building and prevent increases in airborne toxic concentrations; and (3) not be solely relied upon for protection from exposure.

Laboratory hoods will: (1) provide 2.5 cubic feet of work space per two workers, and a hood face velocity of 60-120 linear feet per minute; (2) be used when working with hazardous chemicals, especially those with low toxicity limits or high vapor pressures; (3) not be used as storage areas for chemicals, apparatus, or equipment; (4) not be used to evaporate solvents, other than small quantities of volatiles as necessary to a chemical procedure; (5) be visually inspected and tested for face velocity at least quarterly; and (6) be certified by a licensed vendor upon installation, and be re-certified at least every three years, if moved to another location, or if altered or repaired.

DO NOT ASSUME THAT HOODS ARE WORKING – Check lights and alarms, but also tape a tissue to the lower edge of the hood shield as a visual cue. If the hood is working properly, this will bend strongly into the hood.

Ventilation from glove boxes and other isolation areas will be filtered/scrubbed before entering the main ventilation system.

4.3 Housekeeping, Maintenance and Inspections

Good housekeeping will be maintained in each laboratory, including but not limited to: (1) regular cleaning of floors and work surfaces; (2) not using stairways, halls, and emergency accessways as storage space; and (3) maintaining access to exits, utility controls, and safety equipment.

Chemical-hygiene related equipment (i.e., vent hoods) is subject to regular maintenance and re-assessment. Hoods will be inspected and monitored upon installation, at least every three months while in use, and whenever changes to the ventilation system are made.

Life safety equipment (i.e., emergency showers, eye wash stations) will be visually inspected and flow tested at least quarterly, and maintained, repaired and/or taken out of service as needed. Fire extinguishers will be inspected monthly by Facilities Management staff and serviced annually by a licensed vendor, according to NFPA 10 specifications. First aid kits will be inspected at least annually for stock replacement.

Facility inspections for hygiene, housekeeping, and safety compliance will be conducted three times per year (once each semester, and during the summer session) by the supervisory staff responsible for the specific laboratory. A laboratory inspection checklist is provided in Appendix C.

Electrical connections (circuit boards and other internal connections) and moving parts (pulleys, belts, etc.) must be furnished with covers or guards. Emergency shutoff devices must be located within reach of the operator.

All main gas supply valves will be kept in the CLOSED position when the supplied laboratory equipment is not in use. Benchtop and hood gas spigots will be confirmed as being in the CLOSED position before and after use. Placarding has been posted indicating the CLOSED position of the main valve handle.
5.0 HAZARD EVALUATION, CONTROL AND MONITORING

5.1 Hazard Evaluation

To adequately protect yourself and your colleagues from the hazards of the chemicals with which you work, there are several basic steps to follow:

- Know the physical and health hazards of the substances in your work area and of any substances which may be produced in your work area.
- Know the proper way to handle these substances, including storage, transportation, use and disposal.
- Know what the symptoms of exposure are to the substances in your work area.
- Know the proper emergency procedures.
- Keep a record of the materials you work with, their hazards, etc. (Section 10.1).

This information is readily available from the chemical SDS and other references provided (Section 8.2). It is the laboratory worker’s responsibility to obtain this information.

Physical hazards include fire, explosion, or reactive hazards (Section 3.2). Fire hazards are substances which fall in any of the following categories: combustible liquid, flammable aerosol, flammable gas, flammable liquid, flammable solid, oxidizer, or pyrophoric. Explosion hazards are substances which are classified as explosives or compressed (or liquefied) gases. Reactive substances are hazardous because they are unstable or react violently with common substances (air, water, etc.); this group is composed of organic peroxides, unstable reactive compounds and air- and water-reactive compounds.

Health hazards fall into two categories - acute (short term) and chronic (long term). Chemicals that pose acute hazards are those that fall in any of the following categories: corrosives, irritants, sensitizers, toxic chemicals, highly toxic chemicals, embryotoxins, and agents that affect certain target organs. Chemicals that pose chronic hazards include carcinogens, and agents that affect certain target organs (see Section 3.2).

Permissible Exposure Limits (PEL’s) are the legal exposure limits set by OSHA for airborne concentration of certain chemicals. They are levels at which the average healthy worker experiences no ill health effects, even over the long term. The lower the value, the more hazardous is the substance. PEL information is given in Section 8 of the SDS. The complete tables of PEL’s can be found at www.osha.gov, search for 1910.1000 Table Z-1 and Z-2.

Routes of Exposure. The following potential routes of exposure are defined:

Inhalation - most common - vapors, gases, mists, dusts. Can cause damage to mucous membranes, can be absorbed into blood stream, can be accumulated in the body. Avoided by preventing escape of these materials into the working atmosphere and ensuring adequate ventilation; i.e., avoid spills, work with small amounts, and work in hoods.

Ingestion - entry of substances through the mouth. Can cause damage to mucous membranes, can be absorbed into blood stream, can be accumulated in the body. Caused by splashes, contamination of hands, food, drink, smoking material. Avoided by personal hygiene - wash after handling, especially before eating, smoking, applying cosmetics. Food, drink and smoking materials should not be stored or consumed in areas where chemicals are stored or used. Chemicals should not be tasted. No pipetting by mouth. Leave lab writing implement in lab.

Contact - Splashes, spills. Can cause local skin irritation, be absorbed through skin and produce systemic poisoning, and/or be accumulated in the body. Contact with eyes can cause severe irritation, pain and loss of vision. Avoided by use of personal protective equipment - goggles, face shields, gloves, lab coats, tongs, glove boxes.

Injection - not common. Caused by mechanical injury from glass or metal contaminated by chemicals or accidents with syringes. Avoided by care and personal protective equipment.
5.2 Criteria for Control Measures

1. Some chemicals used may have guidelines for allowed exposure level, such as Threshold Limit Values (TLV) or Permissible Exposure Limits (PEL).

2. When TLV or PEL values exist and are low (see limits below), the user of the chemical must use it in an operating fume hood or other closed system.

3. If TLV or PEL values are not available for a substance, the Lethal Dosage value (LD₅₀) is to be examined, if available. If that is low (see limits below), then the substance must be used in an operating fume hood or other closed system.

4. If the substance has a high vapor pressure (see limits below), meaning that it evaporates quickly at room temperature, it is to be used in an operating fume hood or other closed system. This applies even if the substance with high vapor pressure also has a high TLV, PEL or LD₅₀, as such chemicals are likely to reach their exposure limits in air as quickly as a substance with low TLV, PEL or LD₅₀ and a low vapor pressure.

5. In an uncontained spill situation, if the TLV, PEL, or LD₅₀ values are low (or unknown), or if the substance has a high vapor pressure, evacuate the area and proceed with emergency notification.

6. A fume hood or closed system will be used when one or more of the following applies:
   - The TLV or PEL is below 30 ppm or 600 mg/m³.
   - The LD₅₀ is below 2000 mg/kg (oral) or other Toxic threshold (see Section 3.2).
   - The vapor pressure is above 50 Torr at 20°C or operating temperature, whichever is higher (or boiling point <100°C, if Pᵥap unknown).
   - High chronic toxicity, or on CFR 1910 Subpart Z list (see Section 5.4) or Reproductive toxin (see Section 3.2).

5.3 Personal Protective Equipment (PPE)

Eye protection is required for all personnel and visitors present in locations where chemicals are stored or handled.

- Safety goggles which fit against the face are preferred and are required for users of chemicals.
- Face shields provide more protection, covering the face and neck and should be used (over goggles) when there is likelihood of violent reaction or explosion.
- Lasers require the use of special goggles to prevent eye injury. Heed all warning signs in areas where lasers are in use. Some lasers can cause severe injury in a fraction of a second.
- Prolonged use of UV sources should be avoided. If using UV light, wear UV goggles, even if you are not looking directly at the UV source.

Glove fit and materials. Skin contact is one of the major sources of exposure to chemicals, and the hands are the major point of contact. Proper protective gloves (and other protective clothing, when appropriate) must be worn when working with corrosive or toxic substances and substances of unknown toxicity. Use gloves appropriate to the materials being handled; information on materials selection may be found in the SDS, the “Quick Selection Guide to Chemical Protective Clothing” located in the Stockroom, or similar references. Use large enough gloves so they do not get unnecessarily stretched while you are putting them on (puts micro tears in fabric). Prior to each use, check the gloves for abrasion, punctures or other signs of deterioration. Discard any deteriorated gloves. Gloves should be washed before removing (or turn them inside out as you remove them).

Lab coats and aprons are available for those people working with chemicals. Lab coats do not offer much resistance to chemicals. Plastic or rubber aprons provide better resistance to spills and splashes, but plastic and
synthetic lab coats and aprons should not be used around flammable solvents, as the material can build up a significant static charge. These materials are also flammable and tend to melt onto the wearer and can exacerbate injuries. As with gloves, use apron materials based on the listed recommendations.

**Respirator** use in the laboratory is typically restricted to dust masks for non-hazardous environments. NO activities requiring more than a dust mask will be conducted without express written approval.

**Shields.** Shielding should be used for any operation with the potential for violent reaction or explosion such as when scaling up a reaction, or when working at elevated temperatures. When working with processes which can result in explosions, violent foaming, or aerosol generation, rigid physical protection should be used, as follows:

- Usually, such systems will be located in hoods and should be operated with the plexiglass hood shield lowered as far as possible. For hoods and enclosed benches, a 0.25-in. thick sliding acrylic shield protects a worker from laboratory scale explosions. The shield should be closed whenever hazardous reactions are in progress or whenever hazardous materials are stored in the shielded area. This shielding protects against explosions up to ~ 5 g, but does not protect against metal shards (e.g., exploding ether can). For explosive materials in the 5-20 g range, barriers should be 1-inch (2.5 cm) polyvinyl butyryl resin and heavy metal walls. Hoods should be equipped with mechanical hands for remote manipulation and handling.
- For extra protection, where there is a reasonable probability of violent reaction (work with highly reactive substances), a bench shield should be in place. Barriers such as shields, barricades and guards should be used to completely surround the hazardous area.
- Use a face shield with throat protector for use when bench shields are moved aside and when handling or transporting these substances.
- Use heavy utility gloves when handling these substances.
- Wear a laboratory coat made of slow-burning material and fitted with quick-release cloth buttons.
- Dry boxes used for these materials should have all windows with safety glass overlaid with 0.25 in.-thick acrylic sheet. If possible, wear heavy gloves over the dry box gloves, or use tongs or other devices to remotely manipulate containers.

### 5.4 Environmental Monitoring

**Subpart Z List.**

<table>
<thead>
<tr>
<th>SUBPART Z COMPOUNDS that require air monitoring if PEL exceeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001 - Asbestos - tremolite, anthophyllite, actinolite</td>
</tr>
<tr>
<td>1002 - Coal tar pitch volatiles</td>
</tr>
<tr>
<td>1003 - 4-Nitrophenyl</td>
</tr>
<tr>
<td>1004 - alpha-Naphthylamine</td>
</tr>
<tr>
<td>1006 - Methyl chloromethyl ether</td>
</tr>
<tr>
<td>1010 - Benzidine</td>
</tr>
<tr>
<td>1026 - Hexavalent chromium (5 µg/m3)</td>
</tr>
<tr>
<td>1007 - 3.3’ Dichlorobenzidine and its salts</td>
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<tr>
<td>1008 - bis-Chloromethyl ether</td>
</tr>
<tr>
<td>1009 - beta-Naphthylamine</td>
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<tr>
<td>1030 - Blood-borne pathogens (human blood, tissue)</td>
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<tr>
<td>1045 - Acrylonitrile (1 ppm)</td>
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<tr>
<td>1044 - 1,2-Dibromo-3-chloropropane</td>
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<tr>
<td>1047 - Ethylene oxide</td>
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<tr>
<td>1050 - Methyleneedianiline</td>
</tr>
<tr>
<td>1052 - Methylene chloride (Dichloromethane) (12.5 ppm)</td>
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<tr>
<td>1014 - 2-Acetylaminofluorene</td>
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<tr>
<td>1017 - Vinyl chloride</td>
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<tr>
<td>1015 - 4-(Dimethy lamino)azo benzene</td>
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<tr>
<td>1016 - N-Nitrosodimethyamine</td>
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<tr>
<td>1018 - Inorganic arsenic</td>
</tr>
<tr>
<td>1025 - Lead (30 µg/m3)</td>
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<tr>
<td>1027 - Cadmium and its compounds (5 µg/m3)</td>
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<tr>
<td>1028 - Benzene (0.5 ppm)</td>
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<tr>
<td>1043 - Cotton dust</td>
</tr>
<tr>
<td>1029 - Coke oven emissions</td>
</tr>
<tr>
<td>1011 - 4-Aminodiphenyl</td>
</tr>
<tr>
<td>1012 - Ethyleneimine</td>
</tr>
<tr>
<td>1013 - beta-Propriolactone</td>
</tr>
<tr>
<td>1048 - Formaldehyde (0.5 ppm)</td>
</tr>
<tr>
<td>1051 - 1,3-Butadiene</td>
</tr>
<tr>
<td>1096 - Ionizing radiation</td>
</tr>
</tbody>
</table>

Environmental monitoring must be performed for any regulated substance that specifically requires monitoring (list given in 29 CFR 1910 Subpart Z, 1910.1001 to1910.1096; see below) IF there is reason to believe that the PEL has been or may be exceeded. If a chemical from this list is to be used, it must be used in such a manner as to avoid all exposure (hood if appropriate, or a closed system). This means you must also plan for containment in the event of failure of any such controls. Values in parentheses in the table are 2010 PELs for chemicals that appear in the Chemical Stockroom Inventory; absence of a value does NOT indicate that no PEL exists. To
access OSHA regulations for one of these, go to www.osha.gov and search for 1910.XXXX, where XXXX is the 4-digit number preceding the chemical in the table above.

If air monitoring discloses exposure over the PEL, then further monitoring must be continued as prescribed by the relevant standard and may be discontinued in only accordance with that standard. Employees must be notified in writing of these test results (individually or by posted notice) within 15 days of receipt of same.

**Release Detection Methods.** If any continuous monitoring devices are in use, such as radiation badges or vapor pumps, the results of this will indicate the presence of any substances for which monitoring is being done. This could also include devices as simple as hood flow monitors (alarm, lights, tissue) - check to be sure the hood is operating properly.

Sensory detection of spilled or released chemicals may include:

- Airborn dust, smoke or mist.
- Accumulations of dust, solids, liquid or oil on machines, floors, ledges or counters.
- Unusual odor or taste.
- Sound of gas escaping.
- Hazardous operations being performed in an uncontrolled situation.
- Early exposure symptoms, as listed on the SDS (especially coughing, skin or eye irritation).
- Broken or open containers.
- Hood shuts down while in use.
- Positive findings from monitoring operations.
- Unexplained loss of chemicals from containers.

### 5.5 Employee Exposure Determination

Complaint of exposure must be documented along with decision of appropriate action, signed by the employees involved and the CHO. If no action is taken, reasons should be documented. Evidence of exposure may include:

- Direct skin or eye contact with a chemical or inhalation pursuant to uncontrolled use or spill.
- Odor noticed, especially if working with a chemical with TLV lower than odor threshold.
- Manifestation of health symptoms such as headache, rash, nausea, coughing, tearing, irritation or redness of eyes, irritation of nose or throat, dizziness, loss of motor dexterity or judgment (NOTE that many of these symptoms correspond to those of common illnesses such as colds, flu, etc.; if these symptoms come on suddenly while working with chemicals, however, it may indicate a reaction to something to which you have been exposed).
- Some or all health symptoms disappear when person is removed to fresh air.
- Health symptoms previously complained about reappear soon after person starts working with chemicals again.
- Complaints are received from more than one person in the same work area.

In the event of an exposure, the Laboratory Supervisor and/or the CHO will act as the Exposure Evaluator and interview complainant(s) and/or victim(s), and collect the following information:

- Suspected chemical
- Other chemicals in use by victim
- Other chemicals used in same area
- Other chemicals stored in same area
- Symptoms experienced by victim(s)
- Symptoms on SDS (or otherwise known) for the above chemicals
- What control measures were being (properly) used (hoods, clothing, etc)
- Was any monitoring being done that could have measured actual levels
- Determining how the symptoms compare to the information on the SDS.
• Deciding whether to send the victim for medical evaluation.
• Review of the adequacies of present control measures and safety procedures.

NOTE: The purpose of the exposure evaluation is to determine if any exposure has taken place, not to assign blame.

5.6 Medical Surveillance and Consultation

Medical surveillance will typically be conducted only for those employees working with substances and concentrations for which medical surveillance is required by OSHA.

If you suspect that you or your co-workers have been exposed to hazardous chemicals, report it immediately to the Laboratory Supervisor and/or the CHO. Laboratory employees who work with hazardous chemicals will be given an opportunity to receive medical consultation, including follow-up examination that the attending physician deems necessary, under the following circumstances:

• When an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory;
• Where exposure monitoring reveals an exposure level routinely above the PEL for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements;
• When a release event occurs in the workplace resulting in the likelihood of a hazardous exposure.

Bowdoin College will arrange for consultation with a medical professional who is experienced in treating victims of chemical exposure, and is knowledgeable about which tests or procedures will determine if there has been an exposure.

Information provided to physician will include:

• Identity of hazardous chemical(s) to which the victim may have been exposed.
• Description of conditions under which the exposure occurred, including any quantitative exposure data, if available.
• Description of signs and symptoms of exposure victim is experiencing, if any.

The physician's written report to Bowdoin College will include the following:

• Any recommendation(s) for further medical follow-up.
• Results of the medical examination and any associated tests.
• Any medical condition that may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous chemical found in the workplace.
• A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

The written report SHALL NOT reveal specific findings or diagnoses unrelated to occupational exposure.
6.0 LABORATORY SAFETY PROCEDURES

6.1 General Procedures for Working with Laboratory Chemicals

The most important rule is that everyone involved in laboratory operations, from the highest administrative level to the individual handling the chemicals, must be safety-minded. Safety awareness is not all common sense - there are some very subtle aspects to working safely with chemicals. It is learned and becomes part of everyone's habits only if the issues related to safety are discussed on an ongoing basis and if all parties from professors to researchers to students to stockroom personnel all show an active interest.

It is prudent to minimize all chemical exposures. Because few laboratory chemicals are without hazards, general precautions for handling all laboratory chemicals should be adopted rather than for specific chemicals, as follows:

1. Avoidance of routine exposure. Skin contact with chemicals should be avoided as a cardinal rule. Develop and encourage safe habits, and avoid unnecessary exposure to chemicals by any route. Do not smell or taste chemicals. Vent apparatus that may discharge toxic chemicals (vacuum pumps, instruments, distillation apparatus, etc.) into local exhaust devices. Inspect glove boxes and hoods before use. Do not allow release of toxic substances in cold rooms and warm rooms, since these have contained, recirculated atmospheres.

2. Choice of chemicals. Use only those chemicals for which the quality of the available ventilation system is appropriate.

3. For each chemical that you use, know the physical and health hazards, as determined from the SDS and other appropriate references. Know the proper methods of storing, transporting, using and disposing of each, including what personal protective equipment should be used.

4. Working alone. Avoid working alone in a building. Do not work alone in a laboratory if the procedures being conducted are hazardous.

5. Avoid underestimation of risk. Even for substances with no known significant hazard, exposure should be minimized. For work with substances that present special hazards, special precautions should be taken. One should assume that any mixture is more toxic than its most toxic component and that all substances of unknown toxicity are toxic. Know the safety rules and procedures that apply to the work that is being done. Determine the potential hazards and appropriate safety precautions before beginning any new procedure. Don't take shortcuts. Follow established procedures (such as combining reagents in the proper order).

6. Provide adequate ventilation. The best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by use of hoods and other ventilation devices. See Section 5.2 - Criteria for Control Measures.

7. Know the types of protective and emergency equipment available and their limitations. Use the proper type for each job. See Section 5.3 - Personal Protective Equipment.

8. Observe the PELs, TLVs. The Permissible Exposure Limits of OSHA and the Threshold Limit Values of the American Conference of Governmental Industrial Hygienists should not be exceeded.

9. Be alert to unsafe conditions and actions and call attention to them so that corrections can be made as soon as possible.

10. Avoid storing or consuming food, beverages and tobacco products in areas where chemicals are used or stored.

11. Mouth suction. Do not use mouth suction for pipetting or starting a siphon.

12. Follow the established waste disposal procedures, including traps and scrubbers where appropriate. Each laboratory operation should include plans and training for waste disposal. Deposit chemical waste in appropriately labeled receptacles and follow all other waste disposal procedures of the CHP and the Bowdoin College Hazardous Waste Management Guide. Do not discharge to the sewer concentrated acids or bases, highly toxic, malodorous, or lachrymatory substances, or any substances which might interfere with the biological activity of waste water treatment plants, create fire or explosion hazards, cause structural damage or obstruct flow.

13. Be certain all chemicals are correctly and clearly labeled.

14. Post warning signs when unusual hazards exist, such as radiation, laser operations, extremely toxic or reactive materials, biological hazards, etc.
15. Avoid distracting or startling people working in the laboratory. Practical jokes and horseplay have no place in the chemistry laboratory.

16. Use equipment only for its designed purpose.

17. Position and clamp reaction apparatus to permit easy and safe manipulation without having to move the apparatus. Be sure clamps are secure before relying on them.

18. In case of emergency, vacate the area and notify emergency personnel of the location and nature of the emergency.

19. Planning. Seek information and advice about hazards, plan appropriate protective procedures, and plan positioning of equipment before beginning any new operation. Plan for failure of hoods, cooling water, and containment systems. Get in-lab training as necessary for new operations (see Section 8.3).

20. Unattended operations. Leave lights on, place an appropriate sign in the door and provide for containment of toxic substances in the event of failure of utility service (such as cooling water) to an unattended operation.

21. Use of a hood. Use the hood for operations which might result in release of toxic chemical vapors or dust. (See Section 5.2 - Criteria for Control Measures.) Confirm adequate hood performance before use (indicator light, alarm function and tissue taped to bottom of hood shield). Keep hood closed at all times except when adjustments within the hood are being made. Keep materials stored in hoods to a minimum and do not allow them to block vents or air flow. Leave the hood on when not in active use if toxic substances are present or if uncertain whether adequate laboratory ventilation will be maintained when it is off.

22. Exiting. Wash areas of exposed skin well before leaving the laboratory.

23. Eyewash fountains should be inspected at regular intervals of not less than three months. Emergency showers and other safety equipment should be inspected quarterly. See Section 4.3 – Housekeeping, Maintenance and Inspections.

24. Emergency telephone numbers must be posted outside each laboratory. Location signs must be posted for safety showers, eyewash stations, first aid kits and other safety equipment, and exits.

25. Avoid loose clothing. Rings should be avoided. Solid shoes should be worn and cloth (canvas) sneakers should be avoided. Leather clothing (shoes, belts, watchbands, etc.) that become contaminated with chemicals must be either decontaminated or discarded immediately. Leather can hold chemicals close to the skin for long periods of time. Avoid bare legs or other exposed skin. Do not wear clothing made of synthetic material or fuzzy materials (examples - polyester, rayon, nylon, fleece, mohair, angora) – they are flammable and can make a bad situation worse.

26. Do not put writing implements in your mouth. Keep lab writing implements in the lab.

Food and Beverages. Well-defined areas should be established for storage and consumption of food, beverages and tobacco products, clearly marked (e.g., EATING AREA - NO CHEMICALS). Avoid eating, drinking, smoking, gum chewing, taking medications, or application of cosmetics in areas where laboratory chemicals are present. Wash hands before conducting these activities. Avoid storage, handling or consumption of any of these materials in storage areas, refrigerators, glassware or utensils which are also used for laboratory operations. Emergency medical devices, if necessary, should be double-bagged (epipen, inhaler, etc.).

Glassware. Handle glassware carefully and discard or repair damaged items. Standard precautions include:

- Use adequate gloves when inserting glass tubing into rubber stoppers or corks or rubber tubing. Cut tubing must be firepolished (or rounded) and lubricated before insertion. Use plastic tubing or metal when possible and safe.
- Glass-blowing operations should not be attempted unless proper training has been received. Annealing facilities must be available.
- Glass systems under vacuum, including Dewars, must be handled with extreme care to prevent implosion. Such equipment should be taped or shielded. Only glassware designed for vacuum use should be used for that purpose.
- Wear gloves when cleaning up broken glass.
- Proper instruction in the use of special-purpose glassware must be given, as they can present unusual risks for the first-time user. Examples include separatory funnels containing volatile solvents, which can develop considerable pressure when stoppered and shaken, and large volumetric flasks, which, if held by
the neck and tipped, can snap off in the hand, resulting in severe glass cuts and injection of chemicals into the tissues. Also – Dewars, systems under elevated or reduced pressure, cold traps, Schlenk lines.

6.2 Procedures for Working with Chemicals of Moderate Chronic or High Acute Toxicity

- Chemicals of moderate chronic toxicity include corrosives, irritants, sensitizers, toxics, highly toxics, lacrymatories, oxidizers, embroytoxins, agents affecting the following target organs (narcosis, behavioral changes, decrease in motor function): 1) blood 2) skin 3) eyes or 4) central nervous system. Chemicals of high acute toxicity are those with low LD50's (see Section 3.3) and are considered “particularly hazardous substances” (see Section 3.2).

- Procedures involving the use of any substance with any of these characteristics should be conducted in a hood or other suitable containment device. The hood should be evaluated prior to use to establish that it is providing adequate ventilation and has an average face velocity, with sash at operating height, of not less than 60-120 linear ft/min.

- Protect the hands and forearms by wearing either gloves and a laboratory coat or suitable long gloves (gauntlets) to avoid contact of these materials with the skin.

- If any specific procedures or materials are recommended for control of spills, be sure that the materials are stored close at hand and that their use is clearly understood. An example would be having calcium gluconate on hand when the potential exists for HF spills or exposure.

- After working with toxic materials, wash the hands and arms immediately. Never eat, drink, smoke, chew gum, apply cosmetics, take medicine or store any of these items in areas where toxic substances are being used or stored.

- Areas where highly toxic substances are used or stored should have doors closed and locked when not occupied. This includes 1) use of highly toxic materials or 2) use of any other substance with any of the above characteristics which is volatile (partial pressure > 50 Torr at 20°C or operating temperature, whichever is higher, or if bp <100°C) or 3) those involving solid or liquid substances that may result in the generation of aerosols (such as vigorous gas production or foaming). A warning sign should be posted that includes the name and phone numbers of the user and an alternate, to be contacted in case of emergency.

Records should be kept as part of the laboratory notebook that include the names of person(s) using the chemicals, quantities used and date used. Additional information recorded in the laboratory notebook should include type of gloves used and any special hazards involved.

Containers of these substances should be stored in trays or pans of polyethylene or other chemical resistant material and apparatus should be assembled above trays of this type. These trays and pans should be placed so as not to interfere with the air flow in the hood. Vapors that are discharged from apparatus on a routine basis should be trapped or condensed to avoid venting substantial amounts of toxic vapor in the hood exhaust.

6.3 Procedures for Working with Chemicals of High Chronic Toxicity (see Section 3.2)

A plan for experimental work with and for disposal of these substances is required, must be reviewed by the Laboratory Supervisor, and a copy kept by the experimenter and the reviewer.

An accurate record of the amounts of these substances stored at the work site, along with amounts used, names of user and date used, must be kept as part of the laboratory notebook.

Any volatile substances in these categories should be stored in a ventilated storage area. All chemicals in these categories should be stored in a secondary container or tray having sufficient capacity to contain the material
should the primary container break. All containers of these substances, including reaction mixtures containing these substances must have labels identifying the contents plus the following:

**WARNING! HIGH CHRONIC TOXICITY OR CANCER-SUSPECT AGENT**

Storage areas for these chemicals must have limited access and special signs should be posted. Storage areas should be maintained under constant negative pressure.

All usage and transfers of these substances and mixtures containing these substances must be done in a controlled area. A controlled area is a laboratory or portion thereof, such as a hood or glove box that is designated for the use of highly toxic materials, acute or chronic. The use of a controlled area is not restricted to use of toxic substances, but all personnel who have access to the controlled area must be aware of the nature of the substances present and the precautions necessary. Controlled areas should be clearly marked with a conspicuous sign such as the following:

**WARNING: TOXIC SUBSTANCES IN USE: AUTHORIZED PERSONNEL ONLY**

or

**CANCER-SUSPECT AGENT IN USE: AUTHORIZED PERSONNEL ONLY**

Negative-pressure glove boxes should have at least two volume changes per hour and the pressure should be at least 0.5 in of water (1 Torr) lower than the surroundings and exit gases should be passed through a trap or HEPA filter. Positive-pressure glove boxes must be leak-checked before use with substances in these categories and the exit gases must be passed through a trap or HEPA filter.

Vacuum pumps used with substances in these categories should be protected by high-efficiency scrubbers or HEPA filters and vented into an exhaust hood. Motor-driven vacuum pumps are preferred as they are easier to decontaminate. Decontamination of a vacuum pump should be carried out in an exhaust hood.

6.4 Procedures for Working with Flammable, Pyrophoric, and Reactive Substances

When working with any of these materials, you must wear a non-synthetic lab coat (cotton or flame-resistant) equipped with quick-release fasteners, in addition to the usual gloves and goggles. Wear long pants, long sleeves, closed toed shoes and have the lab coat buttoned. You must NOT wear synthetic material (polyester, nylon, Dacron, rayon, fleece, etc.) as these are not only flammable, they melt onto your skin when burning. You also must not wear fuzzy clothing (such as fleece, angora, and mohair) as these also catch fire very easily.

**Pyrophorics.** Pyrophoric chemicals are those which ignite spontaneously in air below 54°C. Any use of pyrophoric materials requires special training, including accident anticipation. You must demonstrate competency in handling such materials.

**Flammables.** OSHA and NFPA have guidelines on when a chemical is considered flammable. Those guidelines are adopted for use at Bowdoin College. "Flammable" refers to chemicals with a flash point below 100 °F (38°C). Chemicals with flashpoints between 100 and 200 °F (38-93°C) are termed "Combustible". Combustibles (as well as flammables) have caused major fires. Both are considered to be a fire hazard. The degree of hazard depends on the ability to form combustible or explosive mixtures with air (boiling point and upper and lower flammable limits), the ease of ignition of these mixtures (flash point and ignition temperature).

Any pyrophoric, flammable or combustible chemical is to be stored in a flammable solvent storage area or flammable storage cabinet or explosion proof refrigerator/freezer. Flammable substances are to be used in a vented fume hood, away from sources of ignition, and should be handled only in areas free of ignition sources.

The easiest way to prevent fire is to keep ignition sources away from flammable substances. Most chemical vapors are denser than air, hence they will sink and travel along surfaces and can be ignited by a source some
distance from the container. Sources of ignition include any source of flame or spark (including electrical outlets and motors such as hotplate/stirrers), any hot surface and static electricity. All metal containers, including tubing, that contain or are in the vicinity of flammable substances should be grounded to discharge static electricity.

Flammable substances should never be heated by using an open flame. Use steam baths, water baths, oil baths, heating mantles or hot air baths. Flammable substances should never be heated in a closed container. When transferring flammable substances in metal containers, static-generated sparks should be avoided by bonding and the use of ground straps. Metal flammable storage cabinets should be grounded.

Ventilation is one of the most effective ways to prevent the formation of flammable mixtures. Flammable substances should be handled in an exhaust hood whenever appreciable quantities are being transferred from one container to another, used or allowed to stand in open containers, or heated in open containers. One hundred mL of a flammable substance, if evaporated and uniformly mixed in the air, can bring several cubic meters of air up to the lower flammable limit (or PEL).

Substances with flash points at or below room temperature are the most hazardous. Those with boiling points <~40°C have relatively high vapor pressures at room temperature and will very quickly reach the lower flammable limit (often as low as 1-2% by volume). A table of the more commonly used flammable substances is given below, with flash points, boiling points, ignition temperatures and upper and lower flammable limits.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Flash Point (°C)</th>
<th>Boiling Point (°C)</th>
<th>Ignition Temp (°C)</th>
<th>Flammable Limits (% by volume in air)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>-37.8</td>
<td>21.1</td>
<td>175.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Acetone</td>
<td>-17.8</td>
<td>56.7</td>
<td>465.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Benzene</td>
<td>-11.1</td>
<td>80.0</td>
<td>560.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>-30.0</td>
<td>46.1</td>
<td>80.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>-20.0</td>
<td>81.7</td>
<td>245.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>-45.0</td>
<td>35.0</td>
<td>160.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>12.8</td>
<td>78.3</td>
<td>365.0</td>
<td>3.3</td>
</tr>
<tr>
<td>n-Heptane</td>
<td>-3.9</td>
<td>98.3</td>
<td>215.0</td>
<td>1.05</td>
</tr>
<tr>
<td>n-Hexane</td>
<td>-21.7</td>
<td>68.9</td>
<td>225.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Isopropyl alcohol</td>
<td>11.7</td>
<td>82.8</td>
<td>398.9</td>
<td>2.0</td>
</tr>
<tr>
<td>Methyl alcohol</td>
<td>11.1</td>
<td>64.9</td>
<td>385.0</td>
<td>6.7</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>-6.1</td>
<td>80.0</td>
<td>515.6</td>
<td>1.8</td>
</tr>
<tr>
<td>Pentane</td>
<td>-40.0</td>
<td>36.1</td>
<td>360.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Styrene</td>
<td>32.2</td>
<td>146.1</td>
<td>490.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Toluene</td>
<td>4.4</td>
<td>110.6</td>
<td>480.0</td>
<td>1.2</td>
</tr>
<tr>
<td>p-Xylene</td>
<td>27.2</td>
<td>138.3</td>
<td>530.0</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Highly Reactive Chemicals and Explosives. Use of highly reactive chemicals (Section 3.2) can lead to hazardous situations due to the high rate at which they react, especially at elevated temperatures.

Cooling is usually required. If the heat evolved from a reaction involving highly reactive chemicals is not quickly dissipated, the reaction rate keeps increasing and an explosion may result from boiling of the reaction mixture, decomposition of chemicals which are not heat stable (especially peroxides, chlorates and perchlorates) or ignition of flammable reagents. This factor is particularly important when scaling up a reaction. Adequate surface area and coolant must be provided.

Other reactions that can turn violent include those involving concentrated acids or bases, light induced reactions (e.g., hydrogen and chlorine), shock sensitive reactions (acetylides, azides, organic nitrates, nitro compounds, many peroxides), and catalysis of peroxides.

Physical explosions can result from a low-boiling substance brought into sudden contact with a hot substance. Even small explosions (a few milligrams) can result in flying glass and chemicals.
Handle reactive chemicals with all proper safety precautions and appropriate personal protection, including segregation in storage and prohibition on mixing even small quantities with other chemicals without prior approval.

Never mix wastes containing reactive chemicals with any other waste.

Personal protective equipment for use with highly reactive substances:
- Safety goggles.
- Face shield with throat protector for use when bench shields are moved aside and when handling or transporting these substances.
- Heavy gloves (such as electricians use) when handling these substances.
- Laboratory coat made of slow-burning material and fitted with quick-release cloth buttons.
- Barriers such as shields, barricades and guards should also be used to completely surround the hazardous area.

When highly reactive substances are being handled, the laboratory area should be posted with a sign such as:

**WARNING: HIGHLY REACTIVE MATERIALS IN USE!**
**VACATE THE AREA AT THE FIRST SIGN OF ODOR OR EXCESSIVE REACTION.**

A sign such as the following should be posted on the shielded area:

**CAUTION: NO ONE MAY ENTER OR OPEN THIS HOOD FOR ANY REASON DURING THE COURSE OF A HAZARDOUS OPERATION.**

All controls for heating, stirring and manipulating should be operable from outside the shielded area. Vacuum pumps used with highly reactive substances should bear the date of the last oil change. Oil should be changed every month or sooner, if the pump has been used with reactive gases. Pumps should be vented into a hood or trapped. Vent lines should be Tygon, rubber or copper, but avoid copper if used with azides. Flexible lines should be supported so they do not sag.

**Organic Peroxides and Peroxide formers (peroxidizables).** Organic peroxides are extremely sensitive to shock, sparks and other sources of accidental ignition and can be an explosion hazard. The normal rate of decomposition can be greatly accelerated by heat, friction, impact, light and strong oxidizing and reducing agents, causing a violent explosion. Organic peroxides are highly flammable. In-lab training will be provided for users of organic peroxides (see Section 8.3 and Appendix H).

Users of organic peroxide will label any container with the date the container is opened. Once the container has reached the end of its shelf life, the container will be disposed of as hazardous waste. If a part-full container is found to be not labeled with a “date opened” date, then the date received (as noted in the Science Center Electronic Chemical Inventory Program) will be considered as the date opened.

Organic peroxides can form as contaminants in certain reagents upon exposure to air and light. Users of peroxide forming reagents (peroxidizables) will label any container with the date the container was opened. Once the container has reached the end of its shelf life as indicated below, the container will be disposed of as hazardous waste. If a part-full container is found to be not labeled with a “date opened” date, then the date received (as noted in the Science Center Electronic Chemical Inventory Program) will be considered as the date opened. Peroxide test strips will be available upon request through the Science Center stockroom.

Reagent chemicals have been categorized into four classes as described below:

**Class A** – These are chemicals that can form explosive levels of peroxides without being concentrated by evaporation. Once opened, these chemicals can only be stored on site for six months. Once six months has passed, these expired chemicals will be disposed of as hazardous waste.
**Class B** – These chemicals can form explosive levels of peroxides when concentrated by evaporation. Class B chemicals include aldehydes, ethers, and compounds containing benzilic hydrogens and hydroxyls. Once opened, these chemicals can only be stored on site for one year. Once one year has passed, these expired chemicals will be disposed of as hazardous waste.

*Classes C and D described on next page after table.*

### Bowdoin Peroxidizable Chemicals List

<table>
<thead>
<tr>
<th>Class A Peroxidizable (six months)</th>
<th>CAS #</th>
</tr>
</thead>
<tbody>
<tr>
<td>divinyl ether</td>
<td>109-93-3</td>
</tr>
<tr>
<td>divinylacetylene</td>
<td>821-08-9</td>
</tr>
<tr>
<td>isopropyl ether</td>
<td>108-20-3</td>
</tr>
<tr>
<td>potassium metal</td>
<td>7440-09-7</td>
</tr>
<tr>
<td>sodium amide</td>
<td>7782-92-5</td>
</tr>
<tr>
<td>vinylidene chloride</td>
<td>75-35-4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class B Peroxidizable (one year)</th>
<th>CAS #</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetal</td>
<td>98201-60-6</td>
</tr>
<tr>
<td>cumene</td>
<td>98-82-8</td>
</tr>
<tr>
<td>cyclohexene</td>
<td>110-83-8</td>
</tr>
<tr>
<td>diacetylene (cycloxyene)</td>
<td>460-12-8</td>
</tr>
<tr>
<td>dicyclopentadiene</td>
<td>77-73-6</td>
</tr>
<tr>
<td>diethyl ether</td>
<td>60-29-7</td>
</tr>
<tr>
<td>diethylene glycol dimethyl ether (diglyme)</td>
<td>111-96-6</td>
</tr>
<tr>
<td>dioxanes</td>
<td>123-91-1 and others</td>
</tr>
<tr>
<td>ethylene glycol dimethyl ether (glyme)</td>
<td>70992-86-8</td>
</tr>
<tr>
<td>furan</td>
<td>110-00-9</td>
</tr>
<tr>
<td>methyl isobutyl ketone</td>
<td>108-10-1</td>
</tr>
<tr>
<td>methylacetylene</td>
<td>74-99-7</td>
</tr>
<tr>
<td>methylcyclopentane</td>
<td>96-37-7</td>
</tr>
<tr>
<td>tetrahydrofuran</td>
<td>109-99-9</td>
</tr>
<tr>
<td>tetrahydronaphthalene</td>
<td>68412-24-8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class C Peroxidizable (two year)</th>
<th>CAS #</th>
</tr>
</thead>
<tbody>
<tr>
<td>acrylic acid</td>
<td>79-10-7</td>
</tr>
<tr>
<td>acrylonitrile</td>
<td>107-13-1</td>
</tr>
<tr>
<td>butadiene</td>
<td>106-99-0</td>
</tr>
<tr>
<td>chlorobutadiene (chloroprene)</td>
<td>126-99-8</td>
</tr>
<tr>
<td>chlorotrifluoroethylene</td>
<td>79-38-9</td>
</tr>
<tr>
<td>methyl methacrylate</td>
<td>80-62-6</td>
</tr>
<tr>
<td>styrene</td>
<td>100-42-5</td>
</tr>
<tr>
<td>tetrafluoroethylene</td>
<td>116-14-3</td>
</tr>
<tr>
<td>vinyl acetate</td>
<td>108-05-4</td>
</tr>
<tr>
<td>vinyl acetylene</td>
<td>689-97-4</td>
</tr>
<tr>
<td>vinyl chloride</td>
<td>75-01-4</td>
</tr>
<tr>
<td>vinyl pyridine</td>
<td>100-43-6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class D Peroxidizable (date and test)</th>
<th>CAS #</th>
</tr>
</thead>
<tbody>
<tr>
<td>primary and secondary alcohols</td>
<td></td>
</tr>
</tbody>
</table>

---

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kетones, ureas, organic amides and lactams
ethers not listed above
dienes not listed above

**Class C** – These chemicals may autopolymerize as a result of peroxide accumulation. Class C chemicals include compounds containing the allylic structure, vinyl and vinylidene compounds. Once opened, these chemicals can only be stored on site for **two years**. Once two years has passed, these expired chemicals will be disposed of as hazardous waste.

**Class D** – These chemicals only rarely form peroxides with long-term storage and exposure to air and light. Class D compounds include primary and secondary alcohols, ketones, ureas, organic amides and lactams. Containers of these chemicals will be labeled with the date opened and any suspect containers will be tested for the formation of peroxides. A container of Class D reagents will be considered suspect if any discoloration, cloudiness, changes in viscosity, excessive age or other concern is noted. If any peroxide formation is detected, these contaminated chemicals will be disposed of as hazardous waste.

Precautions for handling peroxides and peroxidizables include the following:

- Do not handle a larger quantity than necessary (less than 0.5 g product per run, less than 2.0 g total reactants). Before scaling up to larger quantities, the procedure should be carefully reviewed. Dispose of unused peroxides instead of returning to bottle.
- Clean up all spills immediately. Solutions of peroxides may be adsorbed onto spill absorbent socks.
- Solutions of peroxides in volatile solvents should not be allowed to evaporate, as this will increase the concentration of peroxides. This can also occur during distillation and rotovapping.
- Use ceramic or wooden spatulas with peroxides. Metals can lead to explosive decomposition.
- Keep all sources of heat, spark and flame well away.
- Friction, grinding and other forms of impact should be avoided, especially with solid peroxides. Avoid glass containers with screw cap lids or glass stoppers. Use polyethylene bottles with screw cap lids.
- Store at the lowest possible temperature consistent with solubility and freezing point, but not below the freezing point or point of precipitation of the peroxide.
- Never mix peroxides or peroxidizables with any other wastes.

Peroxides require special handling on a case-by-case basis, depending on the properties of the particular peroxide.

**Explosive Compounds.** Compounds containing the following functional groups also tend to be sensitive to heat and shock: acetylide, azide, diazo, halamine, nitroso, ozonide, peroxide. Compounds containing nitro groups may be highly reactive, especially if certain other substituents, such as halogens, are present. Perchlorates, chlorates, bromates, chlorites and iodates, both organic and inorganic can be highly reactive, especially at elevated temperatures. NEVER pour solutions containing azide down the drain, as it can react with lead and copper piping to form extremely explosive metal azides.

The table below lists known reactive incompatibilities. The lists are not all-inclusive. Check a source such as the SDS or the “Sigma-Aldrich Library of Chemical Safety Data” for other incompatibilities for the chemicals with which you work. Heed all warnings on bottles and in SDS. When transporting, storing, using or disposing of any substance, utmost care must be taken that it cannot accidently come in contact with another with which it is incompatible.

<table>
<thead>
<tr>
<th>COMMON REACTIVE INCOMPATIBILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylenic compounds - explosive in air. Dry acetylides detonate on shock. Incompatible with halogens, alkali metals and salts, alkaline earth metals and salts.</td>
</tr>
<tr>
<td>Anhydrous aluminum chloride - when exposed to moisture, generates HCl gas which can build up pressure.</td>
</tr>
<tr>
<td>Ammonia - reacts with iodine to give nitrogen triiodide, which is explosive. Reacts with hypochlorites (bleach) to give chlorine gas and chloramine (highly toxic). Ammonia and organic halide mixtures can react violently when heated under pressure.</td>
</tr>
</tbody>
</table>
Dry benzoyl peroxide - easily ignited and shock-sensitive. It decomposes spontaneously above 50°C. It is reported to be less reactive if in >20% water.

Carbon disulfide - very toxic and highly flammable. Vapors may be ignited by hot surfaces.

Chlorine - reacts violently with hydrogen and hydrocarbons in sunlight.

Chromium trioxide - pyridine complex may explode if the CrO₃ concentration is too high.

Diazomethane and related compounds - should be treated with extreme caution as they are very toxic. The pure liquids and gases explode easily. Solutions in ether are safer.

Dimethylsulfoxide - decomposes violently on contact with a wide variety of active halogen compounds

Dry ice (solid carbon dioxide) - must be kept in either a container capable of withstanding pressure, or a vented container. Chemicals stored over dry ice should be vented when removed and allowed to warm. Dry ice can produce serious burns.

Drying agents - Ascarite should not be mixed with phosphorus pentoxide as explosion may occur if even a trace of water is present. Moisture-indicating drying agents containing cobalt salts should be restricted to use with gases.

Ethers - sometimes explode during heating, refluxing or evaporating due to the presence of peroxides. Ferrous salts or sodium bisulfite will reduce the peroxides or passage over active basic alumina will remove peroxides. Date ether containers on opening and discard remainder after 6 months.

Ethylene oxide - may explode on heating or under pressure.

Halogenated compounds - Halogenated solvents (chloroform, carbon tetrachloride, methylene chloride and others) react violently with sodium, potassium and other active or finely divided metals.

Hydrogen peroxide - concentrations > 3% can burn the skin and can decompose violently in the presence of iron, copper, chromium and some other metals and their salts.

Lithium aluminum hydride - should not be used to dry methyl ethers or tetrahydrofuran. Fire can result. Carbon dioxide and bicarbonate extinguishers should not be used in fires involving LiAlH₄ as explosive products are formed.

Oxygen - high pressure oxygen (tanks) explodes on contact with oil. Oil should not be used on connections to oxygen cylinders.

Ozone - a highly reactive and toxic gas. The odor is detectable at half the TLV, so if you smell it, it's time to leave. It is formed by the action of ultraviolet light on oxygen (air). When UV sources are used extensively in air or in the presence of oxygen-enriched air, the work should be done in a hood.

Palladium or platinum on carbon, platinum oxide, Raney nickel and other catalysts - should be filtered from hydrogenation reaction mixtures carefully. The recovered catalyst is usually saturated with hydrogen and highly reactive, igniting spontaneously in air. Do not allow the filter cake to dry. Immerse immediately in water. Do not add more catalyst to a flask in which hydrogen is present.

Perchlorates - should be avoided wherever possible. They should not be used to dry organic compounds. Do not expose to dehydrating acids which are strong enough to concentrate the resulting perchloric acid to more than 70% strength (e.g., concentrated sulfuric acid). 70% perchloric acid can be boiled safely at 200°C, but if the boiling acid or hot vapors contact organic matter or easily oxidized inorganic matter, serious explosion will result. Use beaker tongs rather than rubber gloves when handling hot perchloric acid. Perform evaporations in the hood, washing out hood and ducting weekly with water to avoid buildup of explosive residues.

Permanganates are explosive with high concentrations of sulfuric acid.

Peroxides, inorganic - form explosive mixtures when mixed with flammable or combustible substances.

Phosphorus (red or white) forms explosive mixtures with oxidizing agents. White phosphorus ignites in air so it should be stored under water. Phosphorus can react with aqueous hydroxides to form phosphine, which may ignite or explode spontaneously in air.

Phosphorus trichloride - reacts with water to form phosphorus acid, which decomposes on heating to form phosphine, which may ignite or explode spontaneously in air.

Potassium and sodium - Potassium is more reactive than sodium and ignites spontaneously in humid air and in water. It should only be handled immersed in a hydrocarbon solvent such as mineral oil or toluene. Sodium should be stored under hydrocarbon solvent. It will react violently and ignite on contact with water. Sodium may be handled briefly in air. Scraps of either metal can be safely destroyed by reaction with n-butyl alcohol. Neither carbon dioxide nor bicarbonate nor carbon tetrachloride fire extinguishers should be used on alkali metal fires.
Sulfuric acid – should be avoided as a drying agent due to possibilities of spilling and splashing. Concentrated sulphuric acid should not be heated. When diluting, great amounts of heat are released. Pour acid slowly into cold water – use a cold water bath.

Trichloroethylene – reacts under a variety of conditions with potassium and sodium hydroxides to form dichloroacetylene, which ignites spontaneously in air and detonates readily even at dry-ice temperatures. The compound itself is highly toxic.

### CLASSES OF INCOMPATIBLE CHEMICALS

<table>
<thead>
<tr>
<th>Class of Chemical</th>
<th>Incompatible with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids</td>
<td>Bases</td>
</tr>
<tr>
<td>Alkali and alkaline earths carbides</td>
<td>Water, Acids, Halogenated organic compounds, Oxidizing agents, CrO₃, Halogens, Halogenating agents, Hydrogen peroxide and peroxides, Nitric acid, nitrates, Peroxides, Persulfates</td>
</tr>
<tr>
<td>Hydrides</td>
<td>Acids</td>
</tr>
<tr>
<td>Hydroxides</td>
<td>Oxidizing agents</td>
</tr>
<tr>
<td>Oxides</td>
<td>Chromates, dichromates, CrO₃, Halogens, Halogenating agents, Hydrogen peroxide and peroxides, Nitric acid, nitrates, Peroxides, Persulfates</td>
</tr>
<tr>
<td>Peroxides</td>
<td>Halogenates, Peroxides, Persulfates</td>
</tr>
<tr>
<td>Inorganic fluorides</td>
<td>Acids</td>
</tr>
<tr>
<td>Inorganic azides</td>
<td>Acids, Heavy metals and their salts, Oxidizing agents (see list above)</td>
</tr>
<tr>
<td>Inorganic chlorides</td>
<td>Ammonium salts, acids, powdered metals, sulphur, combustibles</td>
</tr>
<tr>
<td>Inorganic cyanides</td>
<td>Acids, strong bases</td>
</tr>
<tr>
<td>Inorganic nitrates</td>
<td>Acids, metals, nitrites, sulfur</td>
</tr>
<tr>
<td>Inorganic nitrites</td>
<td>Acids, oxidizing agents (see list above)</td>
</tr>
<tr>
<td>Inorganic sulfides</td>
<td>Acids</td>
</tr>
<tr>
<td>Organic compounds</td>
<td>Oxidizing agents (see list above)</td>
</tr>
<tr>
<td>Organic acyl halides</td>
<td>Bases, organic hydroxy compounds</td>
</tr>
<tr>
<td>Organic anhydrides</td>
<td>Bases, organic hydroxy compounds</td>
</tr>
<tr>
<td>Halogenated organics</td>
<td>Alkali metals, alkaline earth metals, aluminum, other active metals</td>
</tr>
<tr>
<td>Organic nitro compounds</td>
<td>Strong bases</td>
</tr>
<tr>
<td>Flammable liquids</td>
<td>Oxidizers</td>
</tr>
<tr>
<td>Powdered metals</td>
<td>Acids, oxidizing agents (see list above)</td>
</tr>
</tbody>
</table>

### SPECIFIC CHEMICAL INCOMPATIBILITIES

<table>
<thead>
<tr>
<th>Specific Chemical</th>
<th>Incompatible with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>Oxidizers, hydroxy compounds, ethylene glycol</td>
</tr>
<tr>
<td>Acetone</td>
<td>Mixed concentrated nitric and sulfuric acids</td>
</tr>
<tr>
<td>Acetylene and monosubstituted acetylenes</td>
<td>Halogens, Alkali metals, alkaline earth metals &amp; their salts</td>
</tr>
<tr>
<td>Ammonia and ammonium hydroxide</td>
<td>Halogens, halogenating agents, Silver, mercury, aluminum</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>Acids, powdered metals, flammables, oxidizers, sulfur</td>
</tr>
<tr>
<td>Aniline</td>
<td>Nitric acid, hydrogen peroxide</td>
</tr>
<tr>
<td>Arsenical materials</td>
<td>Any reducing agent</td>
</tr>
</tbody>
</table>
### SPECIFIC CHEMICAL INCOMPATIBILITIES

<table>
<thead>
<tr>
<th>Specific Chemical</th>
<th>Incompatible with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, activated</td>
<td>Oxidizing agents (<em>see list above</em>)</td>
</tr>
<tr>
<td>Chromic acid and CrO$_3$</td>
<td>Acetic acid, glycerol, alcohol, combustibles</td>
</tr>
</tbody>
</table>

### 6.5 Procedures for Working with Gases and Systems Above/Below Ambient Pressure

The Laboratory Supervisor will keep a log of gauge pressures on tanks of compressed gases in use. Detection methods for compressed gas leaks may include:

- Airborn dust, smoke or mist.
- Unusual odor or taste.
- Sound of gas escaping.
- Positive findings from monitoring operations.
- Unexplained decrease in pressure on gas gauges.

Compressed or liquefied gases present hazards if released as they cause high local concentrations, leading to explosive mixtures (if flammable) and displacement of oxygen (asphyxiation hazard). Liquid oxygen is extremely hazardous as it causes a highly explosive atmosphere. Liquid air (and liquid nitrogen exposed to air) contain liquid oxygen. As they boil, the nitrogen boils first, leaving higher and higher concentrations of oxygen in the remaining liquid. Substances that are colder than the boiling point of oxygen (90°K) can cause oxygen to liquefy.

The cryogens used at Bowdoin College include liquid nitrogen, liquid carbon dioxide, liquid helium, and liquid argon. Tanks of these gases must be allowed to vent, as they are not perfectly insulated, thus some liquid evaporates and causes pressure to build up. Hence, tanks of these gases may hiss unless they are empty. Helium, argon, and nitrogen, being relatively nontoxic, can be vented into a lab, as the amount of air displaced by normal venting is insignificant.

For the purpose of rapid visual risk assessment of bottled gases in laboratories by emergency responders, DOT color-coded tags are attached to the dedicated pressure regulators to identify explosive (orange) flammable (red), non-flammable (green), oxygen (yellow), poisonous (white), and reactive (blue) gases.

6.6 Operations Requiring Prior Approval

- Any new procedure should be subjected to peer review, not only from a scientific point of view, but also to assure that all safety considerations are in place prior to implementation. As appropriate, the lab supervisor will conduct in-lab training and complete a Laboratory Specific Training form (see Section 8.3 and Appendix H).

- Approval to proceed with a laboratory task should be obtained when any of the following applies:

- There is a new procedure, process or test, even if it is very similar to older procedures.

- There is a change or substitution of any of the chemicals or apparatus in a procedure or a change in the temperature at which it is to be carried out.

- There is a substantial change in the amount of chemicals used (if the amounts increase by more than 20%).

- There is a failure of any of the equipment used in the process, especially safeguards such as fume hoods (failure to contain the chemicals) or clamp apparatus.

- There are unexpected test results (for example, unexpectedly vigorous reaction, unexpected products formed, etc.). When a test result is different than the predicted, a review of how the new result impacts safety practices must be made.

- Where members of the laboratory staff become ill, suspect exposure, smell chemicals, or otherwise suspect a failure of engineered safeguards.

- Sketch out and describe what you intend to do beforehand. Have a qualified person review your plan for potential safety problems and sign it. The person(s) involved in the project and the reviewer should each keep a copy of this plan.
7.0 CHEMICAL PROCUREMENT, DISTRIBUTION, STORAGE AND DISPOSAL

7.1 Chemical Inventory

Receiving. Before a substance is received, information on proper handling, storage and disposal must be known to those who will be involved (applicable DOT Hazardous Materials and RCRA Hazardous Waste training is discussed in Section 8.3). No container will be accepted without an adequate identifying label and accompanying SDS. All substances will be received in a central location (Druckenmiller Stockroom) by the Laboratory Manager or his assistant for inventory control purposes.

Storage. Flammables will be stored in a flammables cabinet. Corrosives will be stored in a corrosives cabinet. Incompatible chemicals can be stored near each other IF they are not volatile, AND they are in separate secondary containers or trays. Toxic substances must be segregated in a well-identified area with local exhaust ventilation. Chemicals which are highly toxic or highly reactive must be stored in unbreakable secondary containers.

Stored chemicals will be examined at least annually for replacement, deterioration and container integrity. Chemicals may not be stored in laboratory vent hoods.

Microscale. Buy and use only what you need, and avoid especially hazardous chemicals if at all possible. In the lab, downsize whenever possible – if you only need 100 mg, make only that much. Check in the stockroom and on the computer to see if there is some on hand before you order more.

Recycle anything that you can. If you are roto-vapping a pure solvent from solution, consider whether it can be safely reused by your lab or someone else's. If you are working with expensive metals, precipitate them out of the waste solution and perhaps even regenerate the pure metal or a useable form of it (for instance silver chloride is fairly easily converted to silver nitrate). Excess solutions from one experiment might be useable in a subsequent one.

7.2 Rebottling, Transferring, and Transporting Chemicals

Labeling. If you transfer a quantity of a chemical from one container to another for storage, use, or disposal, the new container must also have a label indicating the presence of that chemical and any hazards associated with it. If the container is for storage, add the CAS #, the manufacturer's name & address, the catalog number and the purity. If the container is for solution preparation, be sure that the label contains all the ingredients and their concentrations and hazards. If the container is for waste, refer to Appendix E - Waste Management Reference Guide for proper labeling procedures.

If a quantity of chemical is used in a reaction, label the reaction vessel with the date, the ingredients and the products, and the hazards of the final mixture. This means that you also need to look up the hazards of the products of your reactions. If the hazards are unknown, include that on the label. Since space is limited and the quantity of information may be large, a log may be kept in which you record a container identification number and the required information. This log must remain in the laboratory with the numbered container. The label should clearly indicate the number and your name.

Transferring. When transferring flammable substances from one container to another, metal containers must be grounded. If pouring from one metal container to another, the two metal containers must be wired to each other (use wire with two clips - this is called bonding), and one of the containers must be grounded. Amounts stored in labs should be as small as practical. If a small quantity is transferred for storage, the container it is transferred to must be properly labeled as to contents and hazards. Storage on benchtops and in hoods is not permitted. Exposure to heat or direct sunlight should be avoided. Periodic inventories should be conducted, with unneeded items being returned to the stockroom for storage or disposal.

Transportation. The method of transport of chemicals between stockrooms and laboratories must reflect the potential danger posed by the specific substance. Transportation of chemicals and regulated wastes over public roads and waterways requires compliance with all governing agencies (state and federal DOT and EPA, Coast
Guard, et al) including but not limited to packaging, manifesting (paperwork that must be in hand) and licensing for transportation.

When chemicals are hand-carried, they should be placed in an outside container to protect against breakage and spillage. If the substance is hazardous, the container should include enough absorbent (such as vermiculite or sand) to soak up the substance if it leaks or spills.

If chemicals are carried on a wheeled cart, the cart should be stable under the load. Avoid loading everything on the top shelf of a wheeled cart. Any such cart must have raised lips all around to prevent items from sliding off. If the cart is used on a ramp or uneven surface, it should have higher sides installed. Any such cart should have wheels large enough to cross uneven surfaces (expansion joints, floor drains, elevator entrances, etc.) without tipping or stopping suddenly. Lift and pull carts over these instead of pushing so the wheels don't catch and cause the cart to tip.

Lecture bottles of compressed gases may be hand-carried, but should be in a bucket. Larger compressed gas cylinders must be transported on wheeled carts designed for that purpose. Whenever a cylinder is moved, the metal safety cap must be completely screwed on and the cylinder must be strapped to the cart.

Stairs should only be used for the transportation of nonhazardous chemicals. For hazardous chemicals, use an elevator, pulling carts in and out rather than pushing as noted above. In the event of an emergency such as a power failure or fire alarm, the elevator will default to the ground floor and open its doors, so you may exit with your chemicals. Use stairs when transporting a 4 L Dewar of liquefied gas. Spilled in an elevator, there is the potential for asphyxiation.

7.3 Waste Management

If you are in Druckenmiller, Hatch or Kanbar Halls, you must adhere to the “Bowdoin College Science Center Hazardous Waste Management Guide” (2005), a separate document from this CHP; waste management practices are summarized herein as Appendix E - Waste Management Reference Guide. The aim of the program is to assure that minimal harm to people, other organisms, and the environment will result from the disposal of waste laboratory chemicals. Hazardous waste training is required for all laboratory staff.

Waste Collection. In general, waste that cannot go down the drain should be labeled and returned to the stockroom. Waste containers and labels for them are available in the stockroom. You will go through a separate training session on handling waste (Section 8.3).

When you have waste to dispose of, consult the list of Waste Groups (summarized below) to decide if you can add to a partially filled waste container or if you need to start a new one. If you have a mixture of compounds, a solution, or reaction products (which may be very different from reactants as far as waste is concerned) and are not sure what to do, consult the Laboratory Supervisor or Manager. When in doubt, do not mix wastes.

Pick an appropriate size screw cap container (available in stock room), affix a Hazardous Waste label, and fill in the information. User name is the name of the person in whose lab you are working. Start Date is the date when waste is first placed in the container. If you add a new component, be sure to add it to the list on the bottle. Print clearly using indelible markers. DO NOT fill in the Date Filled - that is done when the bottle is full and ready for disposal. Take care not to spill chemicals on the labels, as it may destroy the label.

If you mistakenly add a compound to a waste bottle which is in a different waste group, don't panic. Note the fact on the bottle and consult with someone to make sure that the wastes are compatible. One of the major reasons for segregating wastes, aside from safety, is to minimize the cost of disposal. For instance, some wastes are more expensive to dispose of than others, so if we can keep the volume of expensive waste down by not mixing in other chemicals, we will reduce the cost of their disposal.

Federally Regulated Wastes. Wastes containing any form of arsenic, barium, cadmium, chromium, lead, mercury, selenium, or silver are regulated and must be kept separate. In addition, wastes containing any of the following organic compounds are also regulated and must be kept separate:
### FEDERALLY REGULATED WASTES

<table>
<thead>
<tr>
<th>Organic Compound</th>
<th>Chemical Hygiene Plan</th>
<th>Chemical Hygiene Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>Carbon tetrachloride</td>
<td>Chlorobenzene</td>
</tr>
<tr>
<td>Chloroform</td>
<td>1,2-Dichloroethane</td>
<td>1,1-Dichloroethylene</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>Tetrachloroethylene</td>
<td>Trichloroethylene</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>1,4-Dichlorobenzene</td>
<td>2,4-Dinitrotoluene</td>
</tr>
<tr>
<td>Hexachlorobenzene</td>
<td>Hexachlorobutadiene</td>
<td>Hexachlorethane</td>
</tr>
<tr>
<td>Nitrobenzene</td>
<td>Pyridine</td>
<td>o-Cresol</td>
</tr>
<tr>
<td>m-Cresol</td>
<td>p-Cresol</td>
<td>Cresol</td>
</tr>
<tr>
<td>Pentachlorophenol</td>
<td>2,4,5-Trichlorophenol</td>
<td>2,4,6-Trichlorophenol</td>
</tr>
<tr>
<td>Endrin</td>
<td>Lindane</td>
<td>Methoxychlor</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>2,4-D</td>
<td>2,4,5-TP (silvex)</td>
</tr>
<tr>
<td>Chlordane</td>
<td>Heptachlor (and hydroxide)</td>
<td></td>
</tr>
</tbody>
</table>

Keep in mind whether products may have formed (e.g., anhydride may now be acid, Grignard (R-Mg-X) may now be Mg(OH)X + R-H, etc.). Non-specific waste groups include the following:

### NON-SPECIFIC WASTE GROUPS

**Organic reactive, corrosive compounds**

DO NOT MIX CHEMICALS WITHIN THIS CATEGORY OR WITH ANY OTHER CATEGORY. Acyl halides, sulfonyl halides, anhydrides, "instant ylids", Grignards, peroxides, peroxidizables. Store individually in labeled, screwcap glass bottle. Return to stockroom for disposal. Do not mix with base (amine, hydroxy, oxide) or water.

**Halogenated organics**

Chlorinated biphenyls

Package separately in labeled, screwcap glass bottle and return to stockroom for disposal.

Other

Examples: dichloromethane, CH$_2$I, any solid halogenated organic dissolved in solution. Store in labeled screwcap glass waste bottle.

**Nonhalogenated organics (liquids and solutions)**

Acetic acid

If < .5M and no other hazardous components, dispose down drain with running water. If >.5 M, store in labeled screwcap glass bottle. Return to stockroom for disposal.

Other acids - propionic, butyric, valeric, phthalic, maleic, benzoic, etc.

Store in labeled screwcap glass waste bottle. Return to stockroom for disposal.

Bases - diethylamine, amines, oxides, etc.

Store in labeled screwcap glass waste bottle. Return to stockroom for disposal.

Ethers - any -C-O-C- structure, cyclic or linear.

Check for peroxides. If peroxides present, reduce. Return (mixture) to stockroom in labeled screwcap glass bottle for disposal.
Neutrals - alkanes, aromatics, ketones, nitriles, alcohols, phenols, aldehydes, amides

Store in labeled screwcap glass waste bottle. Return to stockroom for disposal.

**Inorganics**

Reaction hazards - SnCl₄, H₂O₂, chromic acid, solid oxidizers

DO NOT MIX CHEMICALS WITHIN THIS CATEGORY. Store individually in labeled screwcap glass bottle. Return to stockroom for disposal.

Acids, oxidizing - HNO₃, HClO₄, H₂SO₄ (>6 M)

Store individually in labeled screwcap glass waste bottle. Return to stockroom for disposal. List any other substances present. DO NOT MIX CHEMICALS WITHIN THIS CATEGORY.

Acids, other inorganic - HF, HCl, HBr, HI, dilute H₂SO₄ (≤6 M), etc.

- HF should be kept separate in polyethylene containers. Return to stockroom for disposal.
- Other inorganic acids - if pH 2-12.5 and no other hazardous component, dispose to drain with running water.
- If other hazardous components present, dispose according to procedure for those components.

Bases - NaOH, KOH, NH₄OH, etc. and no other hazardous components

If pH 2-12.5, dispose to drain with running water. If other hazardous components are present, dispose according to procedure for those components. Store bases in labeled screwcap plastic waste bottle. Return to stockroom for disposal.

**Mixtures.** These are generally mixtures that you will be generating, but includes mixed reagents, such as Grignard reagents in organic solvents, BF₃ in methanol, etc. When they become waste, label with all components and return to stockroom for disposal. Do not mix with any other wastes.

**Discarding chemical stocks.** Unlabeled containers of chemicals and solutions should undergo prompt identification and disposal. Before a worker's employment (or student independent study project) in the laboratory ends, chemicals for which that person was responsible should be discarded or returned to storage.

**Frequency of Disposal.** Waste should be removed from laboratories to a central waste storage area when a bottle is full (within 72-hours) or when no more of that waste will be generated. Transport from the institution will be in accordance with DOT regulations.
8.0 HAZARD COMMUNICATION

8.1 Signs and Labels

Safety Signs. OSHA-approved signage will be used to indicate the locations of: (1) the Hazard Communication (SDS) station and emergency contact information; (2) emergency equipment, including eye wash stations, showers, fire extinguishers, and first aid kits; (3) emergency exits; (4) utility panels and control devices; (5) areas of restricted access, specific chemical use or storage, unusual hazards or equipment, and/or where PPE must be worn; and (6) areas in which food and drink are allowed to be stored and/or consumed.

Chemical Labels - General

Manufacturer labels must be neither defaced nor removed. The manufacturer is generally only required to include the following information on the label: the identity of the material, the hazard warnings, the name, address, and emergency phone number of a responsible party from whom additional information can be obtained if needed. NEVER rely on the label as your sole source of hazard information. ALWAYS check the SDS. Most manufacturers also include information on the SDS such as precautionary measures to prevent physical harm (gloves, hood, etc.), instructions in case of exposure, antidotes in case of poisoning, instructions in case of fire or spill, and instructions for storage. Since this information is not required on labels, its absence from the label should not be interpreted to mean that no special measures need to be observed. Likewise, new hazards are continually discovered to be associated with compounds, so existing hazard warnings should be treated as a minimum of information on which to base your method of handling a chemical.

8.2 Safety Data Sheets – General (see GHS revisions in sections 8.3 and 8.4).

Before you begin to work with a chemical, read the SDS, noting the hazards, precautionary measures and symptoms of exposure. If the SDS is not readily available, GET IT and give a copy to the Chemistry Stockroom. Call the supplier and they can fax it here (fax in main Druckenmiller Office is 207-725-3405). Check the supplier’s website – SDS are often available there. Free online sources such as the SigmaAldrich collection at http://www.sigmaaldrich.com/united-states.html are also available. The Chemistry Stockroom also has a paper file of SDS for the Science Center. Copies may be made – be sure to return the original to the notebook.

It is important to realize that SDS are not perfect. Not all SDS are prepared from reliable sources; not all fully describe the known hazardous properties of a substance, and some may describe or imply hazards that are not attributable to that substance. New information also becomes available on the hazards of chemicals, making older SDS obsolete. When reading an SDS remember that information that is ABSENT may be as important as information that is PRESENT. Some of the typical problems found in current SDS’s include:

- No identification of the "target organs" (liver, kidney, lungs, central nervous system, etc.) that are threatened by exposure to the chemical.
- Incomplete PEL statements (should include short-term excursion limits and ceilings).
- A statement that the percent volatile is "zero" or "not available" when the SDS elsewhere states that the vapor pressure is 20 mm (or something similar) at 20°C.
- A statement that the chemical does not burn, coupled with the statement that a particular type of extinguisher should be used.
- Statement that fire situation byproducts "may" be toxic - they either are or are not.
- A description of certain consequences of overexposure, but no criteria to judge what constitutes overexposure.
- A recommendation to wear impervious gloves without specifying the glove material. Most "impervious" gloves will resist penetration for only a few hours at most. In fact, most SDS do not specify glove materials but that information is available elsewhere (see Section 5.3 Personal Protective Equipment).
- Failure to instruct procedures for an unconscious victim.
- Statement to keep removed from ignition sources without an indication of what distance is safe (vapors can travel a long ways and result in flames flashing back to the source).
- Disclaimer statements that say, in effect, that the supplier cannot guarantee that any of the information in the SDS is correct. A statement on an individual item of information, such as "The health effects of this chemical have not been studied." is acceptable, as it is true in many cases.

The “SDS Pocket Dictionary” is an excellent compilation of technical safety information, including explanation of terms used in SDS relating to: (1) signs and symptoms of overexposure; (2) physical and health hazards; and (3) acronyms and general terminology. It gives a discussion of each section required in SDS, what information is in the section and why that information is important (p. 8-17).

Note that any chemical substance sent out to another user or for compositional analysis (with the sole exception of samples of waste being sent out for analysis) must be accompanied by a complete SDS detailing the known properties and hazards of that substance.

8.3 Globally Harmonized System (GHS)

The GHS has been adopted by OSHA and is scheduled to be fully implemented by 6/1/2016. It is a comprehensive system that informs users of a chemical as to its hazards. It has content requirements for both labeling and Safety Data Sheets.

Within a particular hazard there may be up to 5 categories. These may be numbered or lettered. Category 1 or A is the highest degree of hazard, 2 or B next highest, etc. THIS IS AN IMPORTANT DIFFERENCE FROM THE OLDER NFPA SYSTEM (SEE SECTION 8.4). You must be aware of whether you are looking at GHS ratings or NFPA ratings.

GHS Uniform labeling requirements include the following information:

- **Product Identifier** (must be the same as on the SDS)
- **Signal Words** – WARNING, or DANGER in increasing degrees of potential hazard
- **Hazard type and category** – see above.
- **Hazard Statements** – uniformly formatted warnings based on class and category of hazard, supported by one or more of the 11 standardized hazard pictograms
- **Precautionary Statements and Pictograms** – personal protective equipment to be used, recommended engineering controls, and first aid and emergency procedures, supported by one or more of the 8 standardized PPE pictograms (enclosed by a red diamond border (not used in older NFPA system).
- **Supplier Identification** – 24 hour emergency contact information for the supplier and/or manufacturer
- Although all this information is required to be present on labels, ALWAYS check the SDS for hazard information
- New hazards are continually discovered to be associated with compounds, so existing hazard warnings should be treated as a minimum of information on which to base your method of handling a chemical.

GHS Safety Data Sheets (SDS) – see SDS – General (section 8.2)

The SDS is a legal document containing physical properties, hazards and precautionary methods applicable to the chemical. Suppliers of hazardous chemicals are required to furnish SDS to their customers. Employers are required to have SDS on hand for all hazardous chemicals used on the premises; these sheets will be provided in a “Hazard Communication” station in each laboratory or work area.

Pursuant to the 2013 **Globally Harmonized System (GHS)** standards, the SDS must include the following 16 sections in addition to the manufacturer’s contact information:

1. Product identification – trade or chemical name and CAS number
2. Hazard(s) identification – physical, health, and/or environmental – type and category
3. Composition and information on ingredients
4. First aid measures
5. Fire-fighting measures
6. Accidental release measures
7. Handling and storage information
8. Exposure controls / personal protection
9. Physical and chemical properties
10. Stability and reactivity
11. Toxicological information
12. Ecological Information
13. Disposal considerations
14. Transport information
15. Regulatory information
16. Other information

8.4 Older Chemical Hazard Communication Systems – These will most likely be phased out as the GHS is implemented (see Section 8.3).

Many chemical manufacturers use a simple, single word on the label to give an indication of the severity of hazard for that chemical. The three most commonly used, in order of increasing severity of risk, are: CAUTION, WARNING, and DANGER. This is a very general indication.

The National Fire Protection Association (NFPA) has developed its “704M System” which rates risks from 0 (minimum risk) to 4 (maximum risk) in each of three areas: health, flammability and reactivity. THIS IS AN IMPORTANT DIFFERENCE FROM THE NEWER GHS SYSTEM (SEE SECTION 8.3). You must be aware of whether you are looking at GHS ratings or NFPA ratings. The National Paint and Coatings Association (NPCA) has developed a similar system called Hazardous Materials Information System (HMIS). The labels are diamond-shaped and contain four smaller diamonds. Three of the diamonds contain a numerical rating for the three categories given above. These ratings may be found on some bottles of chemicals, but more often, the ratings are only listed in the SDS for the chemical. The fourth diamond is used to designate other special hazards associated with the particular chemical (OXY for oxidizer, W for water-reactive, etc.). Pictorial symbols may also be used. If a chemical container has no label or cannot be identified from the information on the label, the substance must be assumed to be very hazardous in every hazard category and must be treated accordingly.

For a small set of chemicals that are specifically regulated by OSHA as carcinogens, there are specific wording requirements for all containers (see the OSHA Carcinogen List, 29 CFR 1910.1003). The official lists of all carcinogens (a much larger set, see Section 3.2) are continually updated. The information on the bottles and on older (M)SDS may be out of date. For example, some chemicals that were considered carcinogens are no longer on the official lists, but there was probably some data indicating that they had a potential for carcinogenic effects. Even if a chemical is no longer officially listed as a carcinogen, if the bottle says it is, it is probably wise to treat it as if it is a carcinogen.

Material Safety Data Sheets (MSDS) – Old System—see SDS – General (section 8.2)

The MSDS is a legal document containing physical properties, hazards and precautionary methods applicable to the chemical. Suppliers of hazardous chemicals are required to furnish MSDS to their customers. Employers are required to have MSDS on hand for all hazardous chemicals used on the premises; these sheets will be provided in a “Hazard Communication” station in each laboratory or work area. The MSDS were required to include much of the same information as the newer SDS. One way to tell if a distributor has begun the process of updating SDS is that Hazards were listed in Section 3 of MSDS, while they are in Section 2 of SDS (with pictograms).

8.5 Employee Information and Training

Laboratory Standard Training - The purpose of the CHP training program is to assure that all individuals at risk of exposure are adequately informed about the potential hazards in the laboratory.

Employees will receive information and training on the following schedule:
• initially, at the time of hiring and/or assignment to the work area where chemical hazards are present;
• prior to assignments involving new exposure situations; and
• annually, as part of the CHP review and evaluation process.

Information provided to the employee will include the following:

• the contents of the Laboratory Standard (Appendix A);
• the location and ready availability of the CHP;
• the location, availability, and use of the information contained in the Safety Data Sheets (SDS) for the hazardous chemicals present, including the PELs or OSHA-recommended exposure limits for the hazardous chemicals present, and the signs and symptoms associated with exposure to those chemicals.

Training provided to the employee will include the following:

• methods and observations used to detect the presence or release of hazardous chemicals, including monitoring conducted by the employer, personal and/or continuous monitoring devices, physical appearances or odors, etc.;
• how to find information on physical and health hazards associated with the specific chemicals used in the workplace (from the SDS and other sources); and
• measures to be taken to reduce potential exposures, including standard operating procedures, safe work practices, personal protective equipment, and emergency procedures.
• Additional training on procedures specific to your lab may be carried out by your Laboratory Supervisor.

Employee training may be conducted by the CHC representative, Laboratory Supervisor, Laboratory Manager, CHO, or other competent person and logged for the personnel records (Section 10.2). In-lab training will be documented using the Laboratory Specific Training Form (Appendix H).

Emergency and Personal Protection Training. All employees will also be instructed in general emergency procedures, as outlined in Section 9.0. Laboratory Supervisors and other competent persons may additionally be instructed in the location and proper use of emergency equipment, including first aid kits, fire extinguishers, chemical spill kits, and personal protective apparel and equipment, at the discretion of the Department Chair and the CHO.

RCRA/DOT Training. The Laboratory Manager, Laboratory Supervisors, and other designated persons directly responsible for the shipping, handling and/or disposal of chemicals and hazardous wastes (i.e., stockroom personnel) will receive additional training as required by RCRA and/or DOT regulations. This training will be arranged or conducted by the CHO on an annual or as-needed basis for those who qualify.

Student Training. Students who are not paid but are working independently in laboratories will receive the same training as employees. Students in instructional lab courses will be provided training in basic chemical hygiene, safety instructions, emergency procedures, and hazardous waste handling procedures by their instructor or Laboratory Supervisor. Students will be trained prior to their first use of the laboratory, and on an as-needed basis dependent on the experiment procedures.
9.0 EMERGENCY PROCEDURES

9.1 Contact Information

General campus emergency procedures are those outlined by the Bowdoin College Office of Environmental Health and Safety, and posted in each department. Emergency contact numbers and procedures specific to the laboratory setting are summarized on the attached *Emergency Reference Guide (Appendix F)*, and will be posted in each laboratory space. Laboratory Supervisors are responsible for updating the emergency contact names and numbers in their work area.

DO NOT HANDLE AN EMERGENCY ALONE, especially without notifying someone of what has happened. All accidents or near accidents must be reported to the Laboratory Supervisor and/or the CHO immediately, and should be carefully analyzed with the results distributed to all who might benefit.

9.2 Spill and Exposure Response

In the event of a chemical spill:

- If the spill is small and non-life threatening, consult the Laboratory Supervisor, Laboratory Manager, or CHO before attempting to clean it up with kits and/or materials provided. If there are any doubts, do not clean it up yourself.
- If the spill is significant, activate the alarm system, evacuate the area, and contact Security at x3500 to declare an emergency.

In the event of chemical exposure:

- Call Security at x3500. Then stay off the phone so emergency personnel can call you.
- If a person has had skin contact with a chemical, wash the affected area with cool water for at least 15 minutes using the eyewash and/or shower, remove all contaminated clothing, and GET MEDICAL ATTENTION.
- If a person has been overexposed by inhalation, get the victim to fresh air, apply artificial respiration if necessary and if you are qualified, and GET MEDICAL ATTENTION.
- In other cases of exposure, GET MEDICAL ATTENTION and follow the instructions of the medical professional. If you are not trained in basic first aid, GET MEDICAL DIRECTON before inducing vomiting, giving antidotes or applying a "neutralizer" (other than water) to the skin or eyes of the victim.

Reporting:

- The affected person(s), the lab supervisor, and any witnesses must provide all pertinent information to Security; and, if the victim is an employee of the College, file an accident report with Human Resources.
- The CHO must be informed as soon as possible (Call the EHS Office at x3763).

9.3 First Aid

Minor injuries may be treated onsite with the first aid kit provided. However, if chemical exposure is suspected, treat the situation as an emergency and seek outside medical attention according to the posted Emergency Response Guide (Appendix F).

9.4 Evacuation

In the event of alarm sounding, if prudent and can be done so safely, IMMEDIATELY turn off all sources of heat, gas, and electricity, and stabilize any reactions underway. Evacuate the laboratory and building according to the posted route maps, and assemble at the designated rally point, as indicated on the posted *Emergency Egress Plan*. 
In the event that egress from the building is blocked and/or a person is physically incapacitated, designated Areas of Refuge are located in the first and second-floor stairwells and connected to the fire panel area by an intercom system.

9.5 Accident/Incident Reporting

Faculty and staff must report any accident or injury to their Supervisor IMMEDIATELY, and file a report with Human Resources and the EHS Office within 24 hours (this can be submitted online at https://www.bowdoin.edu/facilities/protected/accident-form.shtml) for worker’s compensation and medical insurance purposes. Student injuries must be reported directly to Security (x3500) for response and Cleary documentation purposes.
10.0 RECORDKEEPING

10.1 Laboratory Records

Keep good records in a la notebook of the work that you do, which includes hazard information for the chemicals being used. The information should include chemical name, CAS #, PEL, hazards, special handling precautions, and known symptoms of exposure.

EXAMPLE: Reduction of 1-Octene to n-octane

<table>
<thead>
<tr>
<th>Name</th>
<th>CAS# Codes</th>
<th>CHEMICAL HAZARD INFORMATION</th>
<th>PEL</th>
<th>Special Measures</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Octene</td>
<td>111-66-0</td>
<td>Irritant</td>
<td>-</td>
<td>gloves, hood</td>
<td>burning sensation, coughing, wheezing, shortness of breath laryngitis, headache, nausea vomiting, eye and mucous membrane irritation</td>
</tr>
<tr>
<td>Ethanol</td>
<td>64-17-5</td>
<td>Flammable</td>
<td>1000</td>
<td>gloves, hood</td>
<td>nausea, skin, eye and mucous membrane irritation, dizziness, headache, narcosis</td>
</tr>
<tr>
<td>Chloroplatinic acid (0.2 M)</td>
<td>16941-12-1</td>
<td>Irritant</td>
<td>0.002</td>
<td>gloves, hood</td>
<td>allergic reactions, skin, eye and mucous membrane irritation</td>
</tr>
<tr>
<td>Sodium borohydride (1 M)</td>
<td>16940-66-2</td>
<td>Water-reactive</td>
<td>-</td>
<td>gloves, hood</td>
<td>same as 1-octene above</td>
</tr>
<tr>
<td>Hydrochloric acid (6 M)</td>
<td>7647-01-0</td>
<td>Corrosive</td>
<td>5</td>
<td>gloves</td>
<td>same as 1-octene above</td>
</tr>
<tr>
<td>Pentane</td>
<td>109-66-0</td>
<td>Irritant</td>
<td>600</td>
<td>gloves, hood</td>
<td>skin, eye and mucous membrane irritation</td>
</tr>
<tr>
<td>Silver nitrate</td>
<td>7761-88-0</td>
<td>Highly toxic</td>
<td>.01</td>
<td>gloves</td>
<td>same as 1-octene above</td>
</tr>
<tr>
<td>Silica gel</td>
<td>1343-98-2</td>
<td>Corrosive</td>
<td>6</td>
<td>avoid dust</td>
<td>mucous membrane irritation</td>
</tr>
<tr>
<td>Octane (product)</td>
<td>111-65-9</td>
<td>Irritant</td>
<td>300</td>
<td>gloves, hood</td>
<td>same as 1-octene above</td>
</tr>
</tbody>
</table>

10.2 Personnel Records

Records of exposure monitoring results and medical consultations will be maintained by the CHO for each employee, and be kept, transferred, and/or made available to the employee according to OSHA 29 CFR 1910.1020 (see Sections 5.4, 5.5, 5.6). These records will be maintained for the duration of employment, plus 30 years. Records of required training conducted for new hires, changes in procedure, and annual updates, as outlined in Section 8.3, will be maintained by the CHO.

10.3 Accident Records

Accident and incident reports and supporting documentation will be maintained by the CHO.
11.0 REFERENCES

Regulatory Standards

Occupational Exposures to Hazardous Chemicals in the Laboratory (OSHA 29 CFR 1910.1450)
Toxic and Hazardous Substances (OSHA 29 CFR 1910, Subpart Z)
Highly Hazardous Chemicals, Toxics and Reactives (OSHA 29 CFR 1910.119, Appendix A)
Respiratory Protection Standard (OSHA 29 CFR 1910.134)
Carcinogen List (OSHA 29 CFR 1910.1003)

Technical References


Policies and Procedures

APPENDIX A: LABORATORY STANDARD, OSHA 29 CFR 1910.1450

1910.1450(a)
Scope and application.

1910.1450(a)(1)
This section shall apply to all employers engaged in the laboratory use of hazardous chemicals as defined below.

1910.1450(a)(2)
Where this section applies, it shall supersede, for laboratories, the requirements of all other OSHA health standards in 29 CFR part 1910, subpart Z, except as follows:

1910.1450(a)(2)(i)
For any OSHA health standard, only the requirement to limit employee exposure to the specific permissible exposure limit shall apply for laboratories, unless that particular standard states otherwise or unless the conditions of paragraph (a)(2)(ii) of this section apply.

1910.1450(a)(2)(ii)
Prohibition of eye and skin contact where specified by any OSHA health standard shall be observed.

1910.1450(a)(2)(iii)
Where the action level (or in the absence of an action level, the permissible exposure limit) is routinely exceeded for an OSHA regulated substance with exposure monitoring and medical surveillance requirements paragraphs (d) and (g)(1)(ii) of this section shall apply.

1910.1450(a)(3)
This section shall not apply to:

1910.1450(a)(3)(i)
Uses of hazardous chemicals which do not meet the definition of laboratory use, and in such cases, the employer shall comply with the relevant standard in 29 CFR part 1910, subpart Z, even if such use occurs in a laboratory.

1910.1450(a)(3)(ii)
Laboratory uses of hazardous chemicals which provide no potential for employee exposure. Examples of such conditions might include:

1910.1450(a)(3)(ii)(A)
Procedures using chemically-impregnated test media such as Dip-and-Read tests where a reagent strip is dipped into the specimen to be tested and the results are interpreted by comparing the color reaction to a color chart supplied by the manufacturer of the test strip; and

1910.1450(a)(3)(ii)(B)
Commercially prepared kits such as those used in performing pregnancy tests in which all of the reagents needed to conduct the test are contained in the kit.

1910.1450(b)
Definitions --

Action level means a concentration designated in 29 CFR part 1910 for a specific substance, calculated as an eight (8)-hour time-weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

Assistant Secretary means the Assistant Secretary of Labor for Occupational Safety and Health, U.S. Department of Labor, or designee.

Carcinogen (see select carcinogen).

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 provisions 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.

Chemical Hygiene Plan means a written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment and work practices that (i) are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and (ii) meets the requirements of paragraph (e) of this section.

Combustible liquid means any liquid having a flashpoint at or above 100 deg. F (37.8 deg. C), but below 200 deg. F (93.3 deg. C), except any mixture having components with flashpoints of 200 deg. F (93.3 deg. C), or higher, the total volume of which make up 99 percent or more of the total volume of the mixture.

Compressed gas means:
(i) A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70 deg. F (21.1 deg. C); or

(ii) A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130 deg. F (54.4 deg C) regardless of the pressure at 70 deg. F (21.1 deg. C); or

(iii) A liquid having a vapor pressure exceeding 40 psi at 100 deg. F (37.8 C) as determined by ASTM D-323-72.

**Designated area** means an area which may be used for work with "select carcinogens," reproductive toxins or substances which have a high degree of acute toxicity. A designated area may be the entire laboratory, an area of a laboratory or a device such as a laboratory hood.

**Emergency** means any occurrence such as, but not limited to, equipment failure, rupture of containers or failure of control equipment which results in an uncontrolled release of a hazardous chemical into the workplace.

**Employee** means an individual employed in a laboratory workplace who may be exposed to hazardous chemicals in the course of his or her assignments.

**Explosive** means a chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.

**Flammable** means a chemical that falls into one of the following categories:

(i) **Aerosol, flammable** means an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame protection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening;

(ii) **Gas, flammable** means:

(A) A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less; or

(B) A gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12 percent by volume, regardless of the lower limit.

(iii) **Liquid, flammable** means any liquid having a flashpoint below 100 deg F (37.8 deg. C), except any mixture having components with flashpoints of 100 deg. C) or higher, the total of which make up 99 percent or more of the total volume of the mixture.

(iv) **Solid, flammable** means a solid, other than a blasting agent or explosive as defined in § 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.

**Flashpoint** means the minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite when tested as follows:

(i) Tagliabue Closed Tester (See American National Standard Method of Test for Flash Point by Tag Closed Tester, Z11.24 - 1979 (ASTM D 56-79)) - for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100 deg. F (37.8 deg. C), that do not contain suspended solids and do not have a tendency to form a surface film under test; or

(ii) Pensky-Martens Closed Tester (See American National Standard Method of Test for Flashpoint by Pensky-Martens Closed Tester, Z11.7 - 1979 (ASTM D 93-79)) - for liquids with a viscosity equal to or greater than 45 SUS at 100 deg. F (37.8 deg. C ), or that contain suspended solids, or that have a tendency to form a surface film under test; or

(iii) Setaflash Closed Tester (see American National Standard Method of test for Flash Point by Setaflash Closed Tester (ASTM D 3278-78)).

Organic peroxides, which undergo autoaccelerating thermal decomposition, are excluded from any of the flashpoint determination methods specified above.
**Hazardous chemical** means 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.

Appendices A and B of the Hazard Communication Standard (29 CFR 1910.1200) provide further guidance in defining the scope of health hazards and determining whether or not a chemical is to be considered hazardous for purposes of this standard.

**Laboratory** means 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.

**Laboratory scale** means work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safety manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.

**Laboratory-type hood** means a device located in a laboratory, enclosure on five sides with a movable sash or fixed partial enclosed on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.

Walk-in hoods with adjustable sashes meet the above definition provided that the sashes are adjusted during use so that the airflow and the exhaust of air contaminants are not compromised and employees do not work inside the enclosure during the release of airborne hazardous chemicals.

**Laboratory use of hazardous chemicals** means handling or use of such chemicals in which all of the following conditions are met:

(i) Chemical manipulations are carried out on a "laboratory scale;"

(ii) Multiple chemical procedures or chemicals are used;

(iii) The procedures involved are not part of a production process, nor in any way simulate a production process; and

(iv) "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

**Medical consultation** means a consultation which takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.

**Organic peroxide** means an organic compound that contains the bivalent -O-O- structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical.

**Oxidizer** means a chemical other than a blasting agent or explosive as defined in § 1910.109(a), that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.

**Physical hazard** means a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer pyrophoric, unstable (reactive) or water-reactive.

**Protective laboratory practices and equipment** means those laboratory procedures, practices and equipment accepted by laboratory health and safety experts as effective, or that the employer can show to be effective, in minimizing the potential for employee exposure to hazardous chemicals.

**Reproductive toxins** means chemicals which affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis).

**Select carcinogen** means any substance which meets one of the following criteria:

(i) It is regulated by OSHA as a carcinogen; or
(ii) It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP)(latest edition); or

(iii) It is listed under Group 1 ("carcinogenic to humans") by the International Agency for research on Cancer Monographs (IARC)(latest editions); or

(iv) It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:

(A) After inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m(3);

(B) After repeated skin application of less than 300 (mg/kg of body weight) per week; or

(C) After oral dosages of less than 50 mg/kg of body weight per day.

Unstable (reactive) means a chemical which is the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shocks, pressure or temperature.

Water-reactive means a chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

1910.1450(c) Permissible exposure limits. For laboratory uses of OSHA regulated substances, the employer shall assure that laboratory employees' exposures to such substances do not exceed the permissible exposure limits specified in 29 CFR part 1910, subpart Z.

1910.1450(d) Employee exposure determination --

1910.1450(d)(1) Initial monitoring. The employer shall measure the employee's exposure to any substance regulated by a standard which requires monitoring if there is reason to believe that exposure levels for that substance routinely exceed the action level (or in the absence of an action level, the PEL).

1910.1450(d)(2) Periodic monitoring. If the initial monitoring prescribed by paragraph (d)(1) of this section discloses employee exposure over the action level (or in the absence of an action level, the PEL), the employer shall immediately comply with the exposure monitoring provisions of the relevant standard.

1910.1450(d)(3) Termination of monitoring. Monitoring may be terminated in accordance with the relevant standard.

1910.1450(d)(4) Employee notification of monitoring results. The employer shall, within 15 working days after the receipt of any monitoring results, notify the employee of these results in writing either individually or by posting results in an appropriate location that is accessible to employees.

1910.1450(e) Chemical hygiene plan -- General. (Appendix A of this section is non-mandatory but provides guidance to assist employers in the development of the Chemical Hygiene Plan).

1910.1450(e)(1) Where hazardous chemicals as defined by this standard are used in the workplace, the employer shall develop and carry out the provisions of a written Chemical Hygiene Plan which is:

1910.1450(e)(1)(i) Capable of protecting employees from health hazards associated with hazardous chemicals in that laboratory and

1910.1450(e)(1)(ii) Capable of keeping exposures below the limits specified in paragraph (c) of this section.

1910.1450(e)(2) The Chemical Hygiene Plan shall be readily available to employees, employee representatives and, upon request, to the Assistant Secretary.

1910.1450(e)(3) The Chemical Hygiene Plan shall include each of the following elements and shall indicate specific measures that the employer will take to ensure laboratory employee protection;

1910.1450(e)(3)(i) Standard operating procedures relevant to safety and health considerations to be followed when laboratory work involves the use of hazardous chemicals;
Criteria that the employer will use to determine and implement control measures to reduce employee exposure to hazardous chemicals including engineering controls, the use of personal protective equipment and hygiene practices; particular attention shall be given to the selection of control measures for chemicals that are known to be extremely hazardous; 1910.1450(e)(3)(iii)

A requirement that fume hoods and other protective equipment are functioning properly and specific measures that shall be taken to ensure proper and adequate performance of such equipment; 1910.1450(e)(3)(iv)

Provisions for employee information and training as prescribed in paragraph (f) of this section; 1910.1450(e)(3)(v)

The circumstances under which a particular laboratory operation, procedure or activity shall require prior approval from the employer or the employer's designee before implementation; 1910.1450(e)(3)(vi)

Provisions for medical consultation and medical examinations in accordance with paragraph (g) of this section; 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; and 1910.1450(e)(3)(viii)

Provisions for additional employee protection for work with particularly hazardous substances. These include "select carcinogens," reproductive toxins and substances which have a high degree of acute toxicity. Specific consideration shall be given to the following provisions which shall be included where appropriate:

1910.1450(e)(3)(viii)(A)

Establishment of a designated area;

1910.1450(e)(3)(viii)(B)

Use of containment devices such as fume hoods or glove boxes;

1910.1450(e)(3)(viii)(C)

Procedures for safe removal of contaminated waste; and

1910.1450(e)(3)(viii)(D)

Decontamination procedures.

1910.1450(e)(4)

The employer shall review and evaluate the effectiveness of the Chemical Hygiene Plan at least annually and update it as necessary.

1910.1450(f)

Employee information and training.

1910.1450(f)(1)

The employer shall provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work area.

1910.1450(f)(2)

Such information shall be provided at the time of an employee's initial assignment to a work area where hazardous chemicals are present and prior to assignments involving new exposure situations. The frequency of refresher information and training shall be determined by the employer.

1910.1450(f)(3)

Information. Employees shall be informed of:

1910.1450(f)(3)(i)

The contents of this standard and its appendices which shall be made available to employees;

1910.1450(f)(3)(ii)

the location and availability of the employer's Chemical Hygiene Plan;

1910.1450(f)(3)(iii)

The permissible exposure limits for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard;

1910.1450(f)(3)(iv)

Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory; and

1910.1450(f)(3)(v)

The location and availability of known reference material on the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including, but not limited to, Material Safety Data Sheets received from the chemical supplier.

1910.1450(f)(4)

Training.

1910.1450(f)(4)(i)

Employee training shall include:

1910.1450(f)(4)(i)(A)
Methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.);
1910.1450(f)(4)(i)(B)
The physical and health hazards of chemicals in the work area; and
1910.1450(f)(4)(i)(C)
The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used.
1910.1450(f)(4)(ii)
The employee shall be trained on the applicable details of the employer's written Chemical Hygiene Plan.
1910.1450(g)
Medical consultation and medical examinations.
1910.1450(g)(1)
The employer shall provide all employees who work with hazardous chemicals an opportunity to receive medical attention, including any follow-up examinations which the examining physician determines to be necessary, under the following circumstances:
1910.1450(g)(1)(i)
Whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory, the employee shall be provided an opportunity to receive an appropriate medical examination.
1910.1450(g)(1)(ii)
Where exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the PEL) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance shall be established for the affected employee as prescribed by the particular standard.
1910.1450(g)(1)(iii)
Whenever an event takes place in the work area such as a spill, leak, explosion or other occurrence resulting in the likelihood of a hazardous exposure, the affected employee shall be provided an opportunity for a medical consultation. Such consultation shall be for the purpose of determining the need for a medical examination.
1910.1450(g)(2)
All medical examinations and consultations shall be performed by or under the direct supervision of a licensed physician and shall be provided without cost to the employee, without loss of pay and at a reasonable time and place.
1910.1450(g)(3)
Information provided to the physician. The employer shall provide the following information to the physician:
1910.1450(g)(3)(i)
The identity of the hazardous chemical(s) to which the employee may have been exposed;
1910.1450(g)(3)(ii)
A description of the conditions under which the exposure occurred including quantitative exposure data, if available; and
1910.1450(g)(3)(iii)
A description of the signs and symptoms of exposure that the employee is experiencing, if any.
1910.1450(g)(4)
Physician's written opinion.
1910.1450(g)(4)(i)
For examination or consultation required under this standard, the employer shall obtain a written opinion from the examining physician which shall include the following:
1910.1450(g)(4)(i)(A)
Any recommendation for further medical follow-up;
1910.1450(g)(4)(i)(B)
The results of the medical examination and any associated tests;
1910.1450(g)(4)(i)(C)
Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous workplace; and
1910.1450(g)(4)(i)(D)
A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.
1910.1450(g)(4)(ii)
The written opinion shall not reveal specific findings of diagnoses unrelated to occupational exposure.
1910.1450(h)
Hazard identification.
1910.1450(h)(1)
With respect to labels and material safety data sheets:
1910.1450(h)(1)(i)
Employers shall ensure that labels on incoming containers of hazardous chemicals are not removed or defaced.
Employers shall maintain any material safety data sheets that are received with incoming shipments of hazardous chemicals, and ensure that they are readily accessible to laboratory employees.

The following provisions shall apply to chemical substances developed in the laboratory:

If the composition of the chemical substance which is produced exclusively for the laboratory's use is known, the employer shall determine if it is a hazardous chemical as defined in paragraph (b) of this section. If the chemical is determined to be hazardous, the employer shall provide appropriate training as required under paragraph (f) of this section.

If the chemical produced is a byproduct whose composition is not known, the employer shall assume that the substance is hazardous and shall implement paragraph (e) of this section.

If the chemical substance is produced for another user outside of the laboratory, the employer shall comply with the Hazard Communication Standard (29 CFR 1910.1200) including the requirements for preparation of material safety data sheets and labeling.

Use of respirators. Where the use of respirators is necessary to maintain exposure below permissible exposure limits, the employer shall provide, at no cost to the employee, the proper respiratory equipment. Respirators shall be selected and used in accordance with the requirements of 29 CFR 1910.134.

The employer shall establish and maintain for each employee an accurate record of any measurements taken to monitor employee exposures and any medical consultation and examinations including tests or written opinions required by this standard.

The employer shall assure that such records are kept, transferred, and made available in accordance with 29 CFR 1910.1020.

[Reserved]

The information contained in the appendices is not intended, by itself, to create any additional obligations not otherwise imposed or to detract from any existing obligation.

APPENDIX B: CHEMICAL HYGIENE COMMITTEE
### Laboratory Safety Inspection Checklist

**Date:** ___________________  
**Dept:** ___________________  
**Room #** ___________________

**Person responsible for this area:** ___________________  
**Contact#** ___________________

**Inspector's Name:** ___________________  
**Signature:** ___________________

---

This report is to be completed at the end of each semester and summer session by the Laboratory Supervisor or Instructor, and a copy submitted to the Chemical Hygiene Committee representative in your department by the following dates: **June 20, September 20, and December 20.**

### CHEMICAL HYGIENE PLAN

<table>
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<tr>
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<tr>
<td>A1. The plan is present, visible and accessible in the lab</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2. SDS sheets are accessible to user</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A3. Current inventory for room complete</td>
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### PERSONAL PROTECTIVE EQUIPMENT

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<tr>
<td>B1. Approved eye protection is in use</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>B2. Appropriate gloves are in use as needed</td>
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<td></td>
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<tr>
<td>B3. Other approved PPE available for use</td>
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### LIFE SAFETY EQUIPMENT

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<tr>
<td>C1. Fire extinguishers are in their designated locations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2. Fire blankets are in their designated locations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3. Safety showers tested</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4. Eyewash stations capped, working and clean.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C5. Emergency numbers posted near a working phone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C6. First aid kit stocked and complete (see list in kit)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C7. Clear access to above safety equipment</td>
<td></td>
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### EGRESS/EXITs

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<tr>
<td>D1. Egress/exits not blocked or obstructed</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2. Traffic areas free of tripping hazards</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>D3. Evacuation route posted</td>
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### CHEMICALS

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<tbody>
<tr>
<td>E1. All containers properly labeled</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>E2. Prudent storage practices followed</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>E3. Good housekeeping practiced</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>E4. Gas cylinders restrained, capped, labeled, etc.</td>
<td></td>
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### FUME HOODS

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<th></th>
<th>YES</th>
<th>NO</th>
<th>N/A</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1. Hoods are not being used for storage of material</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2. Hoods are kept clean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3. Indicated maximum sash openings are being used</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
# Bowdoin College Science Center
## Laboratory Safety Inspection Checklist
(con’t)

### HAZARDOUS WASTE

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
<th>N/A</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1. Satellite accumulation area is in compliance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G2. Log is up-to-date</td>
<td></td>
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</tr>
<tr>
<td>G3. No waste is found outside of the accumulation area</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>G4. Spill kit stocked (if present in lab)</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

### MISCELLANEOUS

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
<th>N/A</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1. Broken glass/sharps/ biohazard waste are properly disposed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H2. Mechanical equipment is furnished with guards</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>H3. Only grounded power cords are in use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H4. Safety shielding is used for potential explosion hazards</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>H5. Areas with special or unusual hazards are posted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(EXAMPLE: “Do Not Shut Off Cooling Water”)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H6. Emergency Contact Numbers and Reference Guide are current and clearly posted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H7. No food, drink, etc., present in lab, including refrigerators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Below, indicate the Item # and action being taken to correct any inspection item above which was marked “No” -
(EXAMPLE: “H2 - Vacuum pump guard on order; H3 - Work order for power cord submitted”)
APPENDIX D: CALCULATING CONTAMINATED VOLUME OF AIR

The following equation will give the volume of air in cubic meters which will be brought up to the PEL by vaporizing 10 mL of a liquid compound at room temperature (obviously, if 100 mL were spilled, 10 times the volume of air would be so affected). Even if a heated substance is vaporized, the vapor will be essentially at room temperature. The density must be in g-mL\(^{-1}\). Look up the density, the molecular weight (MW) and find the TWA in the PEL table (TWA, ppm). This assumes no air exchange and that the vapor is evenly distributed.

\[
V = \frac{(\text{density}) \times 2.45 \times 10^5}{(\text{MW})(\text{TWA in ppm})}
\]

As an example, acetone has a density of 0.791, MW = 58, and the TWA is 750 ppm. The volume of contaminated air would be 4.46 m\(^3\).

For chemicals which have an entry only in the TWA (mg-m\(^3\)) column (most solids, which would enter the air largely as dusts and nonvolatile liquids, which would enter the air largely as mists), the corresponding equation for 10 g of a substance would be:

\[
V = \frac{1.00 \times 10^4}{(\text{TWA in mg-m}^3)}
\]

As a reference a small research lab has a volume of about 190 m\(^3\), the medium and large research labs, about 2-3 times as much. Thus spilling 420 mL of acetone in room 248 would exceed the PEL and could result in health effects. It would also trigger the monitoring regulations of the LS.
APPENDIX E: WASTE MANAGEMENT REFERENCE GUIDE

The work you do in the lab may generate Regulated Hazardous Waste. The Laboratory Supervisor will let you know if any waste you generate is regulated. Regulated wastes are collected in a Hazardous Waste Satellite Accumulation Area (SAA) in your lab. Hazardous Waste is brought from these SAA's to the Hazardous Waste Central Accumulation Area (CAA) in the fume hood in Druckenmiller 055, to be transferred to the Hazardous Waste Storage Area by the Laboratory Manager.

You must have completed training in Hazardous Waste Management (see “Bowdoin College Science Center - Hazardous Waste Management Guide”, 2005).

The following rules apply to each Laboratory Hazardous Waste Satellite Accumulation Area (SAA):

1. **Labeling** - All waste containers must have the proper labels indicating responsible person(s), contents list including approximate amounts, container start date, and date filled. Avoid mixing waste types. Label must indicate specific waste chemicals therein, not simply the waste category. Write legibly with a permanent marker.

2. **Containers** - All waste containers must be appropriate, compatible and be provided with adequate secondary containment. A dishpan, glass tray or plastic bucket can provide secondary containment. Only screw-cap containers are acceptable; NO beakers, flasks, etc.

3. **Covers** - All waste containers must be securely closed at all times. Only open the container to add waste, then close and secure immediately.

4. **Storage** - All SAA waste containers must be brought to the Stockroom for transferal to the storage area within 72-hours of filling the container, or before 90 days of service. You may take no more than 90 days to fill a container, but once it is filled or 90 days old it must be removed from the accumulation area within 72-hours. All satellite accumulation areas should be cleared of waste containers at the end of each semester, and at the end of any summer work, in coordination with the periodic laboratory inspections.

5. **Inspection** - Each SAA must be inspected once per week by the Laboratory Supervisor or designated responsible person, and that inspection must be noted in the logbook provided. Inspections must note deteriorated containers or labels, evidence of a release, and other potentially hazardous situations. Inspections may be discontinued during periods when no waste containers are present if so noted in the logbook.
Appendix F. Emergency Response Guide

The Security Communications Center can be reached at x3500 at any time.

YOU ARE IN (Building, Room Name/Number): ____________________________________________

THE EMERGENCY CONTACT PERSON FOR THIS AREA IS: ___________________________ x_______

THE FIRST AID KIT FOR THIS AREA IS LOCATED: ____________________________

THE SDS STATION FOR THIS AREA IS LOCATED: ____________________________

THE SPILL RESPONSE KIT FOR THIS AREA IS LOCATED: ____________________________

<table>
<thead>
<tr>
<th>Emergency</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personal Injury</strong></td>
<td></td>
</tr>
<tr>
<td>Minor cuts, burns, etc.</td>
<td>Administer first aid, have victim visit infirmary for follow-up.</td>
</tr>
<tr>
<td>(Band-Aid variety)</td>
<td></td>
</tr>
<tr>
<td>Serious or life-threatening injury</td>
<td>Call campus emergency at x3500 and describe situation. Security officer will contact ambulance and/or assist.</td>
</tr>
<tr>
<td>Chemical exposure</td>
<td>Call campus emergency at x3500 and describe situation. Security officer will contact ambulance and assist. Use emergency shower or eyewash as necessary. Use fire blanket for privacy (lab coat may be available).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fire or Explosion</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All cases</td>
<td>(1) Activate fire alarm at stairwell or exit; (2) Evacuate, call x3500 and describe situation; (3) use extinguisher after (1) &amp; (2) only if you determine it is appropriate and safe to do so.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical Spills</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-flammable or non-toxic spills</td>
<td>Clean up according to appropriate waste disposal guidelines (refer to SDS), using kits provided.</td>
</tr>
<tr>
<td>Flammable or toxic substances</td>
<td>(1) Activate fire alarm at stairwell or exit; (2) Evacuate, call x3500 and describe situation; (3) use spill kit, absorbent granules or pads to contain the spill if you feel it is appropriate and safe to do so.</td>
</tr>
<tr>
<td>Flammable or toxic vapors</td>
<td>Evacuate the area, get fresh air, and call x3500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cleanup of blood/bodily fluids</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All cases</td>
<td>Requires training. Wear gloves and avoid contact. Contact the Communications Center at x3500, and ask for the Housekeeping Blood Spill Team to assist.</td>
</tr>
</tbody>
</table>
7.D WORKING WITH COMPRESSED GASES
7.D.1 Compressed Gas Cylinders
Precautions are necessary for handling the various types of compressed gases, the cylinders that contain them, the regulators used to control their delivery pressure, the piping used to confine them during flow, and the vessels in which they are ultimately used. Regular inventories of cylinders and checks of their integrity with prompt disposal of those no longer in use are important. (See Chapter 5, section 5.E.6 for information on storing gas cylinders, and Chapter 6, section 6.H, for discussion of the chemical hazards of gases.)

A compressed gas is defined as a material in a container with an absolute pressure greater than 276 kPa, or 40 psi at 21 °C or an absolute pressure greater than 717 kPa (104 psi) at 54 °C, or both, or any liquid flammable material having a Reid vapor pressure greater than 276 kPa (40 psi) at 38 °C. The U.S. Department of Transportation (DOT) has established codes that specify the materials to be used for the construction and the capacities, test procedures, and service pressures of the cylinders in which compressed gases are transported. However, regardless of the pressure rating of the cylinder, the physical state of the material within it determines the pressure of the gas. For example, liquefied gases such as propane and ammonia exert their own vapor pressure as long as liquid remains in the cylinder and the critical temperature is not exceeded.

Prudent procedures for the use of compressed gas cylinders in the laboratory include attention to appropriate purchase, especially selecting the smallest cylinder compatible with the need, as well as proper transportation and storage, identification of contents, handling and use, and marking and return of the empty cylinder to the company from which it was purchased. Empty compressed gas cylinders purchased for the laboratory should be returned to the company and should never be refilled by laboratory personnel. Discourage the practice of purchasing unreturnable lecture bottles to avoid the accumulation of partially filled cylinders and cylinder disposal problems. Encourage trained laboratory personnel to lease the cylinders and, in essence, only purchase the contents.

7.D.1.1 Identification of Contents
Clearly label compressed gas cylinders so they are easily, quickly, and completely identified by trained laboratory personnel. Stencil or stamp identification on the cylinder itself, or provide a durable label that cannot be removed from the cylinder. Do not accept any compressed gas cylinder for use that does not identify its contents legibly by name. Color coding is not a reliable means of identification; cylinder colors vary from supplier to supplier, and labels on caps have no value because many caps are interchangeable. Care in the maintenance of cylinder labels is important because unidentified compressed gas cylinders may pose a high risk and present very high disposal costs. Good practice provides compressed gas cylinders with tags on which the names of users and dates of use can be entered. If the labeling on a cylinder becomes unclear or an attached tag is defaced and the contents cannot be identified, mark the cylinder as contents unknown and contact the manufacturer regarding appropriate procedures.

Clearly label all gas lines leading from a compressed gas supply to identify the gas, the laboratory served, and relevant emergency telephone numbers. The labels, in addition to being dated, should be color-coded to distinguish hazardous gases, such as flammable, toxic, or corrosive substances that are coded with a yellow background and black letters, and inert gases that are coded with a green background and black letters. Post signs conspicuously in areas in which flammable compressed gases are stored, identifying the substances and appropriate precautions, for example, HYDROGEN—FLAMMABLE GAS NO SMOKING—NO OPEN FLAMES

7.D.2 Equipment Used with Compressed Gases
7.D.2.1 Records, Inspection, and Testing
Carry out high-pressure operations only with equipment specifically designed and built for this use and only by those personnel trained especially to use this equipment. Never carry out reactions in, or apply heat to, an apparatus that is a closed system unless it has been designed and tested to withstand pressure. To ensure that the equipment has been properly designed, each pressure vessel should have stamped on it, or on an attached plate, its maximum allowable working pressure, the allowable temperature at this pressure, and the material of construction. Similarly, the relief pressure—the pressure at which the safety system (e.g., rupture disk or safety vent) will be triggered—and setting data should be stamped on a metal tag attached to installed pressure-relief...
devices, and the setting mechanisms should be sealed. Relief devices used on pressure regulators do not require these seals or numbers.

Test or inspect all pressure equipment periodically. The frequency of tests and inspections varies, depending on the type of equipment, how often it is used, and the nature of its usage. Corrosive or otherwise hazardous service requires more frequent tests and inspections. Stamp inspection data on or attach it to the equipment. Testing the entire assembled apparatus with soap solution and air or nitrogen pressure to the maximum operating pressure of the weakest section of the assembled apparatus usually detects leaks at threaded joints, packings, and valves. Alternatively, the apparatus may be pressurized and monitored for pressure drop over time.

Before any pressure equipment is altered, repaired, stored, or shipped, vent it and completely remove all toxic, flammable, or other hazardous material so it can be handled safely. Especially hazardous materials may require special cleaning techniques, which should be solicited from the distributor.

(See section 7.E.1 for further information.)

7.D.2.2 Assembly and Operation
During the assembly of pressure equipment and piping, use only appropriate components, and take care to avoid strains and concealed fractures from the use of improper tools or excessive force. Do not support any significant weight with the tubing in place in a pressure apparatus.

Do not force threads that do not fit smoothly. (See Vignette 7.4.) Do not overtighten fittings. Thread connections must match; tapered pipe threads cannot be joined with parallel machine threads. Use Teflon tape or a suitable thread lubricant on appropriate fittings, (e.g., Teflon tape on pipe fittings only) when assembling the apparatus (see section 7.D.2.2.8). However, never use oil or lubricant on any equipment that will be used with oxygen.

Reject parts having damaged or partly stripped threads (see also section 7.D.2.2.3). In assembling copper-tubing installations, avoid sharp bends and allow considerable flexibility. Copper tubing hardens and cracks on repeated bending. Many metals can become brittle in hydrogen or corrosive gas service. In carbon monoxide atmospheres, some alloys containing nickel or iron can generate carbonyls [e.g., Ni(CO)4] which are toxic when absorbed through the skin or inhaled. Inspect all tubing frequently and re-place when necessary.

Stuffing boxes and gland joints are a likely source of trouble in pressure installations. Give particular attention to the proper installation and maintenance of these parts, including the proper choice of lubricant and packing material.

Shield all reactions under pressure and carry them out as remotely as possible, for example, with valve extensions and behind a heavy shield or with closed- circuit TV monitoring if needed.

Do not fill autoclaves and other pressure-reaction vessels more than half full to ensure that space remains for expansion of the liquid when it is heated. Do not make leak corrections or adjustments to the apparatus while it is pressurized; rather, depressurize the system before mechanical adjustments are made.

A regulator or step-down pressure valve should be used to pressurize low-pressure equipment from a high-pressure source. After pressurizing equipment with a high-pressure source, the equipment should either be disconnected or the connecting piping/tubing should be vented to atmospheric pressure. This will prevent the accidental buildup of excessive pressure in the low-pressure equipment due to leakage from the high-pressure source. For example, after completing the pressurization of an autoclave with a compressed gas cylinder, the cylinder valve should be closed, the delivery regulator backed off to 0 psig, and the lines between the cylinder and the autoclave vented.

Do not use vessels or equipment made partly or entirely of silver or copper or alloys containing more than 50% copper in contact with acetylene or ammonia. Do not let those vessels or equipment made of metals susceptible to amalgamation (e.g., copper, brass, zinc, tin, silver, lead, and gold) come into contact with mercury. This warning includes equipment that has soldered and brazed joints.

Place prominent warning signs in any area where a pressure reaction is in progress so that personnel entering the area will be aware of the potential risk.

VIGNETTE 7.4
Hydrogen leak from jammed cylinder cap
A technician tried to remove the cap from a 2,000-psi 42-L hydrogen cylinder. Unable to un- screw the cap by hand, the technician attempted to use a wrench to loosen it. While doing this, the cylinder valve opened causing hydrogen to begin leaking from the cylinder. Unable to close the valve because the cap was still jammed in place, the technician pulled the fire alarm and the building was evacuated. Fire personnel were not successful in removing the cylinder cap. The cylinder was placed in an area with adequate ventilation and allowed to empty.

Bowdoin College
Office of Environmental Health and Safety
Chemical Hygiene Plan
Subsequent investigation showed that the cylinder valve plug had not been properly replaced in the valve by a previous user. Valve caps must be in place for the storage of flammable, toxic, and corrosive gas cylinders. The loose valve plug was responsible for jamming the cylinder cap. Further, the wrench used in the attempt to remove the cap was not the correct tool; a strap or other nonsparking wrench should have been used.

7.D.2.2.1 Pressure-Relief Devices
Protect all pressure or vacuum systems and all vessels that may be subjected to pressure or vacuum by properly designed, installed, and tested pressure-relief devices. Experiments involving highly reactive materials that might explode or undergo rapid decomposition with gas evolution (tetrafluoroethylene and hydrogen cyanide are two examples) may also require the use of special pressure-relief devices and may need to be operated at a fraction of the permissible working pressure of the system.

Examples of pressure-relief devices include the rupture-disk type used with closed-system vessels and the spring-loaded safety valves used with vessels for transferring liquefied gases. The following precautions are advisable in the use of pressure-relief devices:

- In addition to the pressure setting, pressure-relief device and associated fittings (tubing, connectors, etc.) must be properly sized and configured to provide a sufficient rate of pressure relief while preventing overpressurization. The diameter of the relief device and fittings and the presence of bends and angles are important considerations that should be addressed by a qualified and trained person or persons.
- The materials of construction must be considered, taking into account the compatibility of the chemicals being handled with the relief components.
- The temperature rating of the relief device must be sufficient. Heat conduction via tubing and fittings can cause the relief device to reach high temperatures, depending on the apparatus design.
- Orient pressure-relief devices with the vent side of the device directed away from the operator or other personnel. Also vent the relief device into an appropriate trap to catch flammable solvent, reaction solids, etc., avoiding spray into the work-space in the event of a release and minimizing the potential of a fire and aiding clean up. The relief device and trap must be supported so that they are not dislodged or thrown due to the thrust resulting from sudden venting.
- The maximum setting of a pressure-relief device is the rated maximum allowable working pressure (MAWP) established for the vessel or for the weakest member of the pressure system at the operating temperature. The operating pressure should be less than the system MAWP. In the case of a system protected by a spring-loaded relief device, the maximum operating pressure should be from 5 to 25% lower than the rated working pressure, depending on the type of safety valve and the importance of leak-free operation. In a system protected by a rupture-disk device, the maximum operating pressure should be approximately two-thirds of the rated MAWP; the exact figure is governed by the fatigue life of the disk used, the temperature, and load pulsations.
- Vent pressure-relief devices that may discharge toxic, corrosive, flammable, or otherwise hazardous or noxious materials in a safe and environmentally acceptable manner such as scrubbing or diluting with nonflammable streams.
- Do not install valves or other shutoff devices between pressure-relief devices and the equipment they are to protect. Similarly, do not install shutoff valves downstream of the relief device and take care to ensure that the relief vent is not blocked or restricted. Tubing and piping downstream of such devices must be at least the same diameter as the fitting on the vent side of the relief device.
- Only qualified persons should perform maintenance work on pressure-relief devices.
- Inspect and replace pressure-relief devices periodically.
- Gas manifolds, compressors, and other sources of high-pressure gas used to supply an apparatus, and which can be isolated from the apparatus by valving, should also be protected by a properly designed pressure-relief device.

7.D.2.2.2 Pressure Gauges
The proper choice and use of a pressure gauge involve several factors, including the flammability, compressibility, corrosivity, toxicity, temperature, and pressure range of the fluid with which it is to be used. Generally, select a gauge with a range that is double the working pressure of the system.

A pressure gauge is normally a weak point in any pressure system because its measuring element must operate in the elastic zone of the metal involved. The resulting limited factor of safety makes careful gauge selection and use mandatory and often dictates the use of accessory protective equipment. The primary element of the most commonly used gauges is a Bourdon tube, which is usually made of brass or bronze and has soft-soldered connections. More expensive gauges are available that have Bourdon tubes made of steel, stainless steel, or other special metals and welded or silver-soldered connections. Accuracies vary from ±2% for less expensive
pressure gauges to ±0.1% for higher quality gauges. Use a diaphragm gauge with corrosive gases or liquids or with viscous fluids that would destroy a steel or bronze Bourdon tube. Consider alternative methods of pressure measurement that may provide greater safety than the direct use of pressure gauges. Such methods include the use of seals or other isolating devices in pressure tap lines, indirect observation devices, and remote measurement by strain-gauge transducers with digital readouts. Mount pressure gauges so that they are easily read during operation. Pressure gauges often have built-in pressure-relief devices. Care must be taken to ensure that, in the event of failure, this relief device is oriented away from personnel.

7.D.2.2.3 Piping, Tubing, and Fittings
The proper selection and assembly of components in a pressure system are critical safety factors. Considerations include the materials used in manufacturing the components, compatibility with the materials to be under pressure, the tools used for assembly, and the reliability of the finished connections. Use no oil or lubricant of any kind in a tubing system with oxygen because the combination produces an explosion hazard. Use all-brass and stainless steel fittings with copper or brass and steel or stainless steel tubings, respectively. Fitting of this type must be installed correctly. Do not mix different brands of tube fittings in the same apparatus assembly because construction parts are often not interchangeable.

7.D.2.2.4 Glass Equipment
Avoid glassware for work at high pressure when ever possible. Glass is a brittle material, subject to unexpected failures due to factors such as mechanical impact and assembly and tightening stresses. Poor annealing after glassblowing can leave severe strains. Glass equipment, such as rotameters and liquid-level gauges, incorporated in metallic pressure systems should be installed with shutoff valves at both ends to control the discharge of liquid or gaseous materials in the event of breakage. Mass flowmeters are available that can replace rotameters in desired applications.

7.D.2.2.5 Plastic Equipment
Except as noted below, avoid the use of plastic equipment for pressure or vacuum work unless no suitable substitute is available. These materials can fail under pressure or thermal stress. Only use materials that are appropriately rated or recommended for that particular service. Tygon and similar plastic tubing have quite limited applications in pressure work. These materials can be used for hydrocarbons and most aqueous solutions at room temperature and moderate pressure. Reinforced plastic tubing that can withstand higher pressures is also available. However, loose tubing under pressure can cause physical damage by its own whipping action. Details of permissible operating conditions must be obtained from the manufacturer. Because of their very large coefficients of thermal expansion, some polymers have a tendency to expand greatly on heating and to contract on cooling. This behavior can create a hazard in equipment subjected to very low temperatures or to alternating low and high temperatures. Plastic tubing may also disrupt electrical grounding and thus present a static electricity hazard. The use of plastic tubing with flammable gases or liquids is not recommended if grounding is an issue.

7.D.2.2.6 Valves
Valves come in a wide range of materials of construction, pressure and temperature ratings, and type. The materials of construction (metal, elastomer, and plastic components) must be compatible with the gases and solvents being used. The valves must be rated for the intended pressure and temperature. Ball valves are preferred over needle valves because their status (on/off) can be determined by quick visual inspection. Use metering or needle valves only when careful flow control is important to the operation. Micrometers can sometimes be used with needle valves to allow quick determination of the status.

7.D.2.2.7 Gas Monitors
Electronic monitors and alarms are available to prevent hazards due to asphyxiant, flammable, and many toxic gases. Consider their use especially if large quantities or large cylinders of these gases are in use. Make sure the monitor is properly rated for the intended purpose as some detectors are subject to interference by other gases.

7.D.2.2.8 Teflon Tape Applications
Use teflon tape on tapered pipe thread where the seal is formed in the thread area. Tapered pipe thread is commonly found in applications where fittings are not routinely taken apart (e.g., general building piping applications). Do not use Teflon tape on straight thread (e.g., Swagelok) where the seal is formed through gaskets or by other
metal-to-metal contacts that are forced together when the fitting is tightened [e.g., Compressed Gas Association (CGA) gas cylinder fittings or compression fittings]. Metal-to-metal seals are machined to tolerances that seal without the need of Teflon tape or other gasketing materials. If used where not needed, as on CGA fittings, Teflon tape only spreads and weakens the threaded connections and can plug up lines that it enters accidentally.

7.D.3 Handling and Use of Gas Cylinders
Gas cylinders must be handled carefully to prevent accidents or damage to the cylinder. Leave the valve protection cap in place until the cylinder is secured and ready for use. Do not drag, roll, slide, or allow gas cylinders to strike each other forcefully. Always transport them on approved wheeled cylinder carts with retaining straps or chains. The plastic mesh sleeves sometimes installed by vendors are intended only to protect the paint on the cylinder and do not serve as a safety device.

Secure compressed gas cylinders firmly at all times. A clamp and belt or chain, holding the cylinder between waist and shoulder to a wall, are generally suitable for this purpose. In areas of seismic activity, secure gas cylinders both toward the top and toward the bottom. Individually secure cylinders; using a single restraint strap or chain around a number of cylinders is often not effective. Locate cylinders in well-ventilated areas. Although inert gases are not exposure hazards, they can produce conditions of oxygen depletion that could lead to asphyxiation. Vent pressure-relief devices protecting equipment that is attached to cylinders of flammable, toxic, or otherwise hazardous gases to a safe place. (See section 7.D.2.2.1 for details.)

Standard cylinder-valve outlet connections have been devised by CGA to prevent the mixing of incompatible gases due to an interchange of connections. Outlet threads used vary in diameter; some are male and some are female, some are right-handed and some are left-handed. In general, right-handed threads are used for nonfuel and water-pumped gases, and left-handed threads are used for fuel and oil-pumped gases. Information on the standard equipment assemblies for use with specific compressed gases is available from the supplier. To minimize undesirable connections that may result in a hazard, use only CGA standard combinations of valves and fittings in compressed gas installations. Avoid the assembly of miscellaneous parts (even of standard approved types). Do not use an adapter or cross-thread a valve fitting. Examine the threads on cylinder valves, regulators, and other fittings to ensure that they correspond to one another and are undamaged.

Place cylinders so that the rotary cylinder valve handle at the top is accessible at all times. Open cylinder valves slowly, and only when a proper regulator is firmly in place and the attachment has been shown to be leakproof by an appropriate test. Close the cylinder valve as soon as the necessary amount of gas has been released. Valves should be either completely open or completely closed. Install flow restrictors on gas cylinders to minimize the chance of excessive flows. Never leave the cylinder valve open when the equipment is not in use. This precaution is necessary not only for safety when the cylinder is under pressure but also to prevent the corrosion and contamination that would result from diffusion of air and moisture into the cylinder when it is emptied. Most cylinders are equipped with hand-wheel valves. Those that are not should have a spindle key on the valve spindle or stem while the cylinder is in service. Use only wrenches or other tools provided by the cylinder supplier to remove a cylinder cap or to open a valve. Never use a screwdriver to pry off a stuck cap or pliers to open a cylinder valve. If valve fittings require washers or gaskets, check the materials of construction before the regulator is fitted.

If the valve on a cylinder containing an irritating or toxic gas is being opened outside, the worker should stand upwind of the cylinder with the valve pointed downwind, away from personnel, and warn those working nearby in case of a possible leak. If the work is being done inside, open the cylinder only in a laboratory chemical hood or specially designed cylinder cabinet. Install a differential pressure switch with an audible alarm in any chemical hood dedicated for use with toxic gases. In the event of chemical hood failure, the pressure switch should activate an audible alarm warning personnel.

7.D.3.1 Preventing and Controlling Leaks
Check cylinders, connections, and hoses regularly for leaks. Convenient ways to check for leaks include a flammable gas leak detector (for flammable gases only) or looking for bubbles after application of soapy water or a 50% glycerin–water solution. At or below freezing temperatures, use the glycerin solution instead of soapy water. Bubble-forming solutions designed for leak testing are commercially available. When the gas to be used in the procedure is a flammable, oxidizing, or highly toxic gas, check the system first for leaks with an inert gas (helium or nitrogen) before introducing the hazardous gas. Only leak-test solutions specifically designed for oxygen compatibility may be used to test for oxygen leaks; do not use soap solutions because they may contain oils that can react violently with the oxygen.

The general procedures discussed in Chapter 6, section 6.C, can be used for relatively minor leaks, when the indicated action can be taken without exposing personnel to highly toxic substances. The leaking cylinder can be
moved through populated portions of the building, if necessary, by placing a plastic bag, rubber shroud, or similar device over the top and taping it (preferably with duct tape) to the cylinder to confine the leaking gas. If there is any risk of exposure, call the environmental health and safety office and evacuate the area before the tank is moved.

If a leak at the cylinder valve handle cannot be remedied by tightening a valve gland or a packing nut, take emergency action and notify the supplier. Never attempt to repair a leak at the junction of the cylinder valve and the cylinder or at the safety device; consult with the supplier for instructions.

When the nature of the leaking gas or the size of the leak constitutes a more serious hazard, an approved SCBA and protective apparel may be required, and personnel may need to be evacuated (see Chapter 6, section 6.C.2). If toxic gas is leaking from a cylinder, donning of protective equipment and evacuation of personnel are required. Cylinder coffins are also available to encapsulate leaking cylinders. (See Chapter 6, section 6.H for more information.)

7.D.3.2 Pressure Regulator
Pressure regulators are required to reduce a high-pressure supplied gas to a desirable lower pressure and to maintain a satisfactory delivery pressure and flow level for the required operating conditions. They are available to fit many operating conditions over a range of supply and delivery pressures, flow capacities, and construction materials. All regulators are typically of a diaphragm type and are spring-loaded or gas-loaded, depending on pressure requirements. They can be single-stage or two-stage. Under no circumstances should oil or grease be used on regulator valves or cylinder valves because these substances may react with some gases (e.g., oxygen).

Each regulator is supplied with a specific CGA standard inlet connection to fit the outlet connection on the cylinder valve for the particular gas. Never tamper with or adapt regulators for use with gases for which they are not designed. Likewise, never substitute the fittings that are on either the cylinder side or downstream (low-pressure) side of a vendor-supplied regulator. Instead, purchase a regulator designed for use with the specific cylinder, and use adapters only on the downstream side of the regulator. Unqualified persons must never attempt to repair or modify regulators.

Check regulators before use to verify they are free of foreign objects and to correct for the particular gas. Regulators for use with noncorrosive gases are usually made of brass. Special regulators made of corrosion-resistant materials are available for use with such gases as ammonia, boron trifluoride, chlorine, hydrogen chloride, hydrogen sulfide, and sulfur dioxide. Because of freeze-up and corrosion problems, regulators used with carbon dioxide gas must have special internal design features and be made of special materials. Regulators used with oxidizing agents must be cleaned specially to avoid the possibility of an explosion on contact of the gas with any reducing agent or oil left from the cleaning process.

All pressure regulators should be equipped with spring-loaded pressure-relief valves (see section 7.D.2.2.1 for further information on pressure-relief devices) to protect the low-pressure side. When used on cylinders of flammable, toxic, or otherwise hazardous gases, vent the relief valve to a laboratory chemical hood or other safe location. Avoid the use of internal-bleed-type regulators. When working with hazardous gases, installing flow-limiting devices after the regulator is recommended in order to add a level of control on the system. Remove regulators from corrosive gases immediately after use and flush with dry air or nitrogen. Bubblers of any type (e.g., mercury, oil) are not suitable for use as pressure regulators and should not be used. (For information about reducing the use of mercury in laboratories, see Chapter 5, section 5.B.8.)

7.D.3.3 Flammable Gases
Keep all sources of ignition away from cylinders of flammable gases and ensure that these cylinders will not leak. Always keep connections to piping, regulators, and other appliances tight to prevent leakage, and keep the tubing or hoses used in good condition. Perform leak checks periodically. Flash arrestors are recommended for flammable gases. Do not interchange regulators, hoses, and other appliances used with cylinders of flammable gases with similar equipment intended for use with other gases. Ground cylinders properly to prevent static electricity buildup, especially in very cold or dry environments. Separate cylinders containing flammable gases from cylinders of oxidizing gases by at least 20 ft or by a 5-ft-high fire-resistant partition with a minimum 30-minute fire rating. Store all cylinders containing flammable gases in a well-ventilated place. Never store reserve stocks of such cylinders in the vicinity of cylinders containing oxidizing gases including oxygen, fluorine, and chlorine. Never store oxidizing gases near flammable liquids.

7.E WORKING WITH HIGH OR LOW PRESSURES AND TEMPERATURES
Work with hazardous chemicals at high or low pressures and high or low temperatures requires planning and
special precautions. For many experiments, extremes of both pressure and temperature, such as reactions at elevated temperatures and pressures and work with cryogenic liquids and high vacuum, must be managed simultaneously. Carry out procedures at high or low pressures with protection against explosion or implosion by appropriate equipment selection and the use of safety shields. Provide appropriate temperature control and interlocks so that heating or cooling baths cannot exceed the desired limits even if the equipment fails. Take care to select and use glass apparatuses that can safely withstand thermal expansion or contraction at the designated pressure and temperature extremes.

7.E.1 Pressure Vessels
Perform high-pressure operations only in special chambers equipped for this purpose. Trained laboratory personnel should ensure that equipment and pressure vessels are appropriately selected, properly labeled and installed, and protected by pressure-relief and necessary control devices. Vessels must be strong enough to withstand the stresses encountered at the intended operating pressures and temperatures. The vessel material must not corrode when it is in contact with its contents. The material should not react with the process being studied, and the vessel must be of the proper size and configuration. Never carry out reactions in, or apply heat to, an apparatus that is a closed system unless it has been designed and tested to withstand the generated pressure.

Pressure-containing systems designed for use at elevated temperatures should have a positive-feedback temperature controller. Manual control using a simple variable autotransformer, such as a variac, is not good practice. The use of a backup temperature controller capable of both recording temperatures and shutting down an unattended system is strongly recommended. (See section 7.D.2, above.)

7.E.1.1 Records, Inspection, and Testing
In some localities, adherence to national codes such as the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME, 1992) is mandatory. Selection of containers, tubing, fittings, and other process equipment, along with the operational techniques and procedures, must conform to the constraints necessary for high-pressure service. The proper selection and assembly of components in a pressure system are critical safety factors. Compatibility of materials, tools used for assembly, and the reliability of connections are all key considerations.

Each pressure vessel in a laboratory should have a stamped number or fixed label plate that uniquely identifies it. Information such as the maximum allowable working pressure, allowable temperature at this pressure, material of construction, and burst diagram should be readily available. Information regarding the vessel's history should include temperature extremes it has experienced, any modifications and repairs made to the original vessel, and all inspections or test actions it has undergone. Similarly, the relieving pressure and setting data should be stamped on a metal tag attached to installed pressure-relief devices. Relief devices used on pressure regulators do not require these seals or numbers.

Test or inspect all pressure equipment periodically. The interval between tests or inspections is determined by the severity of the usage the equipment has received. Corrosive or otherwise hazardous service requires more frequent tests and inspections. Stamp inspection data on or attach it to the equipment. Pressure vessels may be subjected to nondestructive inspections such as visual inspection, penetrant inspection, acoustic emissions recording, and radiography. However, hydrostatic proof tests are necessary for final acceptance. They should be performed as infrequently as possible but before the vessel is placed into initial service, every 10 years thereafter, after a significant repair or modification, and if the vessel experiences overpressure or overtemperature. Testing the entire apparatus with soap solution and air or nitrogen pressure to the maximum allowable working pressure of the weakest section of the assembled apparatus usually detects leaks at threaded joints, packings, and valves.

Pressure-test and leak-test final assemblies to ensure their integrity. Trained laboratory personnel are strongly advised to consult an expert on high-pressure work as they design, build, and operate a high-pressure system. Finally, exercise extreme care when disassembling pressure equipment for repair, modification, or decommissioning. (See Vignette 7.5.) Personnel should be familiar with the safe procedures for depressurizing the system, including the order in which to open valves or fittings. Wear protective equipment in case a line or vessel that is opened contains material under pressure. Good practice is to cover the vessel or fitting being opened with a cloth or paper towel to contain any spray should the contents be unknowingly pressurized.

7.E.1.2 Pressure Reactions in Glass Equipment
Run reactions under pressure in metal equipment, not glass, if at all possible. For any reaction run on a large scale (>10 g total weight of reactants) or at a maximum pressure in excess of 690 kPa (100 psi), use only
procedures involving a suitable high-pressure autoclave or shaker vessel. If glass is required because of material-
of-construction concerns, use a metal reactor with a glass or Teflon liner instead of a glass vessel under pressure. Glass pressure reaction vessels are available from several vendors and are designed for use in the 0- to 200-psig range. However, it is sometimes convenient to run very small scale reactions at low pressures in a small sealed glass tube or in a thick-walled pressure bottle of the type used for catalytic hydrogenation. For any such reaction, laboratory personnel should be fully prepared for the significant possibility that the sealed vessel will burst. Gases must be vented properly and adequate precautions taken for ventilation. When using glass under pressure, assume that the glass will fail. Take every precaution to prevent injury from flying glass or from corrosive or toxic reactants by using suitable shielding. Often a mesh is provided around the glassware to catch pieces should the vessel rupture. Seal centrifuge bottles with rubber stoppers clamped in place, wrapped with friction tape and shielded with a metal screen or wrapped with friction tape and surrounded by multiple layers of loose cloth toweling, and clamped behind a good safety shield. Some bottles are typically equipped with a head-containing inlet and exhaust gas valves, a pressure gauge, and a pressure-relief valve. If a pressure gauge is not used, estimate the maximum internal pressure by calculation prior to beginning the experiment to ensure that the maximum allowable pressure is not exceeded. When corrosive materials are used, use a Teflon pressure-relief valve. The preferred source of heat for such vessels is steam, because an explosion in the vicinity of an electrical heater could start a fire and an explosion in a liquid heating bath would scatter hot liquid around the area. Carry out any reaction of this type in a chemical hood, labeled with signs that indicate the contents of the reaction vessel and the explosion risk.

Fill glass tubes under pressure no more than three-quarters full. Appropriate precautions using the proper shielding must be taken for condensing materials and sealing tubes. Vacuum work can be carried out on a Schlenk line, an apparatus used for work with air-sensitive compounds, as long as proper technique is used. The sealed glass tubes can be placed either inside pieces of brass or iron pipe capped at one end with a pipe cap or in an autoclave containing some of the reaction solvent (to equalize the pressure inside and outside the glass tube). The tubes can be heated with steam or in a specially constructed, electrically heated sealed-tube furnace that is controlled thermostatically and located to direct the force of an explosion into a safe area. When the required heating has been completed, allow the sealed tube or bottle to cool to room temperature. Wrap sealed bottles and tubes of flammable materials with cloth toweling, place behind a safety shield, and cool slowly, first in an ice bath and then in dry ice. After cooling, the clamps and rubber stoppers can be removed from the bottles prior to opening. Use PPE and apparel, including shields, masks, coats, and gloves, during tube-opening operations. Note that NMR tubes are often thin-walled and should only be used for pressure reactions in a special high-pressure probe or in capillary devices.

Examine newly fabricated or repaired glass equipment for flaws and strains under polarized light. Never rely on corks, rubber stoppers, and rubber or plastic tubing as relief devices to protect glassware against excess pressure; use a liquid seal, Bunsen tube, or equivalent positive-relief device. With glass pipe, use only proper metal.

VIGNETTE 7.5
Injury while working on equipment under pressure
A laboratory person connected a fresh helium cylinder to a gas manifold. When the cylinder valve was opened to pressurize the system, a slight hissing sound was heard from a fitting that connected a flexible metal hose to the manifold pressure regulator. An attempt was made to repair the leak while the system was still pressurized. On applying a wrench to the fitting, the flexible hose disconnected completely and whipped off the regulator, striking the individual on the head, cheek, and abdomen, causing bruising and lacerations.

This incident highlights the importance of deenergizing systems and processes prior to disassembly or maintenance.

7.E.2 Liquefied Gases and Cryogenic Liquids
Cryogenic liquids are materials with boiling points of less than −73 °C (−100 °F). Liquid nitrogen, helium, argon, and slush mixtures of dry ice with isopropyl alcohol are the materials most commonly used in cold traps to condense volatile vapors from a gas or vapor stream. In addition, oxygen, hydrogen, and helium are often used in the liquid state.

The primary hazards of cryogenic liquids are frostbite, asphyxiation, fire or explosion, pressure buildup (either slowly or due to rapid conversion of the liquid to the gaseous state), and embrittlement of structural materials. The extreme cold of cryogenic liquids requires special care in their use. The vapor that boils off from a liquid can cause the same problems as the liquid itself. The fire or explosion hazard is obvious when gases such as oxygen, hydrogen, methane, and acetylene are used.
Air enriched with oxygen can greatly increase the flammability of ordinary combustible materials and may even cause some noncombustible materials to burn readily (see Chapter 6, sections 6.G.4 and 6.G.5). Oxygen-saturated wood and asphalt have been known to explode when subjected to shock. Because oxygen has a higher boiling point (−183 °C) than nitrogen (−195 °C), helium (−269 °C), or hydrogen (−252.7 °C), it can be condensed out of the atmosphere during the use of these lower boiling-point cryogenic liquids. With the use of liquid hydrogen particularly, explosive conditions may develop. (See Chapter 6, sections 6.F.3 and 6.G.2, for further discussion.)

Furnish all cylinders and equipment containing flammable or toxic liquefied gases (not vendor-owned) with a spring-loaded pressure-relief device (not a rupture disk) because of the magnitude of the potential risk that can result from activation of a nonresetting relief device. Commercial cylinders of liquefied gases are normally supplied only with a fusible-plug type of relief device, as permitted by DOT regulations. Protect pressurized containers that contain cryogenic material with multiple pressure-relief devices. Cryogenic liquids must be stored, shipped, and handled in containers that are designed for the pressures and temperatures to which they may be subjected. Materials that are pliable under normal conditions can become brittle at low temperatures. Dewar flasks, which are used for relatively small amounts of cryogenic material, should have a dust cap over the outlet to prevent atmospheric moisture from condensing and plugging the neck of the tube. Special cylinders that are insulated and vacuum-jacketed with pressure-relief valves and rupture devices to protect the cylinder from pressure buildup are available in capacities of 100 to 200 L.

A special risk to personnel is skin or eye contact with the cryogenic liquid. Because these liquids are prone to splash owing to the large volume expansion ratio when the liquid warms up, wear eye protection, preferably chemical splash goggles and a face shield, when handling liquefied gases and other cryogenic fluids. Do not transfer liquefied gases from one container to another for the first time without the direct supervision and instruction of someone who is experienced in this operation. Transfer very slowly to minimize boiling and splashing.

Do not allow unprotected parts of the body to come in contact with uninsulated vessels or pipes that contain cryogenic liquids because extremely cold material may bond firmly to the skin and tear flesh if separation or withdrawal is attempted. Even very brief skin contact with a cryogenic liquid can cause tissue damage similar to that of frostbite or thermal burns, and prolonged contact may result in blood clots that have potentially very serious consequences. Gloves must be insulated, impervious to the fluid being handled, and loose enough to be tossed off easily in case the cryogenic liquid becomes trapped close to the skin. Never wear tight gloves when working with cryogenic liquids. Trained laboratory personnel are also encouraged to wear long sleeves when handling cryogenic fluids. Handle objects that are in contact with cryogenic liquids with tongs or potholders.

Ventilate the work area well. Virtually all liquid gases present the threat of poisoning, explosion, or, at a minimum, asphyxiation in a confined space. Major harmful consequences of the use of cryogenic inert gases, including asphyxiation, are due to boiling off of the liquid and pressure buildup, which can lead to violent rupture of the container or piping.

Take special care when handling liquid hydrogen. In general, do not transfer liquid hydrogen in an air atmosphere because oxygen from the air can condense in the liquid hydrogen, presenting a possible explosion risk. Take all precautions to keep liquid oxygen from organic materials: spills on oxidizable surfaces can be hazardous. Although nitrogen is inert, its liquefied form can be hazardous because of its cryogenic properties and because displacement of air oxygen in the vicinity can lead to asphyxiation followed by death with little warning. Fit rooms that contain appreciable quantities of liquid nitrogen (N2) with oxygen meters and alarms. Do not store liquid nitrogen in a closed room because the oxygen content of the room can drop to unsafe levels.

Do not fill cylinders and other pressure vessels that are used for the storage and handling of liquefied gases to more than 80% capacity, to protect against possible thermal expansion of the contents and bursting of the vessel by hydrostatic pressure. If the possibility exists that the temperature outside of the cylinder may increase to greater than 30°C, a lower percentage (e.g., 60%) of capacity should be the limit.

7.E.2.1 Cold Traps and Cold Baths

Choose cold traps that are large enough and cold enough to collect the condensable vapors. Check cold traps frequently to make sure they do not become plugged with frozen material. After completion of an operation in which a cold trap has been used, isolate the trap from the source, remove from the coolant, and vent to atmospheric pressure in a safe and environmentally acceptable way. Otherwise, pressure could build up, creating a possible explosion or sucking pump oil into a vacuum system. Cold traps under continuous use, such as those used to protect inert atmosphere dryboxes, should be electrically cooled, and their temperature should be monitored with low-temperature probes.
Use appropriate gloves and a face shield to avoid contact with the skin when using cold baths. Wear dry gloves when handling dry ice. Do not lower the head into a dry ice chest because carbon dioxide is heavier than air and asphyxiation can result. The preferred liquids for dry-ice cooling baths are isopropyl alcohol or glycols; add dry ice slowly to the liquid portion of the cooling bath to avoid foaming. Avoid the common practice of using acetone—dry ice as a coolant; the alternatives are less flammable, less prone to foaming and splattering with dry ice, and less likely to damage some trap components (O-rings, plastic). Dry ice and liquefied gases used in refrigerant baths should always be open to the atmosphere. Never use them in closed systems, where they may develop uncontrolled and dangerously high pressures.

Exercise extreme caution in using liquid nitrogen as a coolant for a cold trap. If such a system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere. The oxygen could then combine with any organic material in the trap to create a highly explosive mixture. Therefore, do not open a system that is connected to a liquid nitrogen trap to the atmosphere until the liquid nitrogen Dewar flask or container has been removed. A liquid nitrogen-cooled trap must never be left under static vacuum. Also, if the system is closed after even a brief exposure to the atmosphere, some oxygen may have already condensed. Then, when the liquid nitrogen bath is removed or when it evaporates, the condensed gases will vaporize, producing a pressure buildup and the potential for explosion. The same explosion hazard can be created if liquid nitrogen is used to cool a flammable mixture that is exposed to air. Caution must be applied when using argon, for instance as an inert gas for Schlenk or vacuum lines, because it condenses as a colorless solid at liquid nitrogen temperature. A trap containing frozen argon is indistinguishable from one containing condensed solvent or other volatiles and presents an explosion hazard if allowed to warm without venting.

7.E.2.2 Selection of Low-Temperature Equipment
Select equipment used at low temperatures carefully because temperature can dramatically change characteristics of materials. For example, the impact strength of ordinary carbon steel is greatly reduced at low temperatures, and failure can occur at points of weakness, such as notches or abrupt changes in the material of construction. When combinations of materials are required, consider the temperature dependence of their volumes so that leaks, ruptures, and glass fractures are avoided. For example, O-rings that provide a good seal at room temperature may lose resilience and fail to function on chilled equipment.

Stainless steels containing 18% chromium and 8% nickel retain their impact resistance down to approximately –240 °C; the exact value depends heavily on special design considerations. The impact resistance of aluminum, copper, nickel, and many other nonferrous metals and alloys increases with decreasing temperatures. Use special alloy steels for liquids or gases containing hydrogen at temperatures greater than 200 °C or at pressures greater than 34.5 MPa (500 psi) because of the danger of weakening carbon steel equipment by hydrogen embrittlement.

7.E.2.3 Cryogenic Lines and Supercritical Fluids
Design liquid cryogen transfer lines so that liquid cannot be trapped in any nonvented part of the system. Experiments in supercritical fluids include high pressure and should be carried out with appropriate protective systems.

7.E.3 Vacuum Work and Apparatus
Vacuum work can result in an implosion and the possible hazards of flying glass, spattering chemicals, and fire. Set up and operate all vacuum operations with careful consideration of the potential risks. Although a vacuum distillation apparatus may appear to provide some of its own protection in the form of heating mantles and column insulation, this is not sufficient because an implosion could scatter hot flammable liquid. Use an explosion shield and a full-face shield to protect laboratory personnel, and carry the procedure out in a laboratory chemical hood. Glassware under vacuum should be kept behind a shield or hood sash, taped, or resin (plastic) coated.

Equipment at reduced pressure is especially prone to rapid pressure changes, which can create large pressure differences within the apparatus. Such conditions can push liquids into unwanted locations, sometimes with undesirable consequences. Do not allow water, solvents, and corrosive gases to be drawn into a building vacuum system. When the potential for such a problem exists, use a cold trap. Water aspirators are not recommended.

Protect mechanical vacuum pumps by cold traps, and vent their exhausts to an exhaust hood or to the outside of the building. If solvents or corrosive substances are inadvertently drawn into the pump, change the oil before any further use. (Oil contaminated with solvents, mercury, and corrosive substances must be handled as hazardous waste.) It may be desirable to maintain a log of pump usage as a guide to length of use and potential contaminants in the pump oil. Cover the belts and pulleys on vacuum pumps with guards. (See section 7.C.2 for a
7.E.3.1 Glass Vessels
Although glass vessels are frequently used in low-vacuum operations, evacuated glass vessels may collapse violently, either spontaneously from strain or from an accidental blow. Therefore, conduct pressure and vacuum operations in glass vessels behind adequate shielding. Check for flaws such as star cracks, scratches, and etching marks each time a vacuum apparatus is used. These flaws can often be noticed if the vessel is held up to a light. Use only round-bottom or thick-walled (e.g., Pyrex) evacuated reaction vessels specifically designed for operations at reduced pressure. Do not use glass vessels with angled or squared edges in vacuum applications unless specifically designed for the purpose (e.g., extra thick glass). Repaired glassware must be properly annealed and inspected with a cross-polarizer before vacuum or thermal stress is applied. Never evacuate thin-walled, Erlenmeyer, or round-bottom flasks larger than 1 L.

7.E.3.2 Dewar Flasks
Dewar flasks are under high vacuum and can collapse as a result of thermal shock or a very slight mechanical shock. Shield them, either by a layer of fiber-reinforced friction tape or by enclosure in a wooden or metal container, to reduce the risk of flying glass in case of collapse. Use metal Dewar flasks whenever there is a possibility of breakage. Styrofoam buckets with lids can be a safer form of short-term storage and conveyance of cryogenic liquids than glass vacuum Dewar flasks. Although they do not insulate as well as Dewar flasks, they eliminate the danger of implosion.

7.E.3.3 Desiccators
If a glass vacuum desiccator is used, it should be made of Pyrex or similar glass, completely enclosed in a shield or wrapped with friction tape in a grid pattern that leaves the contents visible and at the same time guards against flying glass if the vessel implodes. Plastic (e.g., polycarbonate) desiccators reduce the risk of implosion and may be preferable but should also be shielded while evacuated. Solid desiccants are preferred. Never carry or move an evacuated desiccator. Take care opening the valve to avoid spraying the desiccator contents from the sudden inrush of gas.

7.E.3.4 Rotary Evaporators
Glass components of the rotary evaporator should be made of Pyrex or similar glass. Completely enclose in a shield to guard against flying glass should the components implode. Gradually increase rotation speed and application of vacuum to the flask whose solvent is to be evaporated.

7.E.3.5 Assembly of Vacuum Apparatus
Assemble vacuum apparatus to avoid strain. Joints must allow various sections of the apparatus to be moved if necessary without transmitting strain to the necks of the flasks. Support heavy apparatus from below as well as by the neck. Protect vacuum and Schlenk lines from overpressurization with a bubbler. Gas regulators and metal pressure-relief devices must not be relied on to protect vacuum and Schlenk lines from overpressurization. If a slight positive pressure of gas on these lines is desired, the recommended pressure range is not in excess of 1 to 2 psi. This pressure range is easily obtained by proper bubbler design (depth of the exit tubing in the bubbler liquid).

Place vacuum apparatus well back onto the bench or into the laboratory chemical hood where it will not be inadvertently hit. If the back of the vacuum setup faces the open laboratory, protect it with panels of suitably heavy transparent plastic to prevent injury to nearby personnel from flying glass in case of implosion.

Discussion of vacuum pumps.)
APPENDIX H: Bowdoin College Laboratory Specific Training

This form is to be filled out for each laboratory worker after training on procedures specific to the laboratory in which he or she works. One copy should be kept by the Laboratory Supervisor, one copy by the worker and one sent to the Chair of the Chemical Hygiene Committee (currently Judith Foster, Chemistry). If additional training occurs, complete and file a new form indicating that.

**PLEASE PRINT HERE AND SIGN AT BOTTOM**

Laboratory Supervisor ___________________________ Date ______________________

Trainee ___________________________ Building/Lab # ______________________

Check off the following training that has been accomplished to the extent that the Laboratory Supervisor and the trainee are both satisfied that the trainee is qualified to perform operations involving these hazards without further supervision.

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**SIGNATURES**

Supervisor ___________________________ Date ______________________

Trainee ___________________________ Date ______________________