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1.1 INTRODUCTION

The Occupational Safety and Health Administration's (OSHA) laboratory health standard (Occupational Exposures to Hazardous Chemicals in Laboratories (29 CFR 1910.1450)) requires employers of laboratory employees to implement exposure control programs and convey chemical health and safety information to laboratory employees working with hazardous materials. Specific provisions of the standard require: (1) laboratory inspections; (2) establishment of standard operating procedures for routine and "high hazard" laboratory operations; (3) research protocol safety reviews for procedures, activities or operations which the employer believes to be of a sufficiently hazardous nature to warrant prior approval; (4) exposure assessments; (5) medical consultations/exams; (6) training; (7) labeling of chemical containers; and (8) the management of chemical safety information sheets (Safety Data Sheets) and other safety reference materials. The intent of this standard is to ensure that laboratory employees are apprised of the hazards of chemicals in their work area, and that appropriate work practices, procedures and controls are in place to protect laboratory employees from chemical health and safety hazards. Although students are not covered by OSHA, Yale’s Chemical Hygiene Plan covers all personnel in a research laboratory, including faculty, staff, and students.

The standard operating procedures (laboratory practices and engineering controls) recommended in this manual identify the safeguards that should be taken when working with hazardous chemicals. These safeguards will protect laboratory personnel from unsafe conditions in the vast majority of situations. There are instances, however, when the physical and chemical properties, the proposed use, the quantity used for a particular purpose or the toxicity of a substance will be such that either additional, or fewer, controls might be appropriate to protect the laboratory worker. Professional judgment is essential in the interpretation of these standard operating procedures, and individual laboratories may modify these procedures to meet their specific uses and operational needs. These modifications and lab-specific SOPs must be in writing and maintained by the laboratory.

The manner in which Yale University is complying with each of the elements in OSHA’s Laboratory Standard is detailed in this Laboratory Chemical Hygiene Plan. This plan is available on the EHS website: ehs.yale.edu. Additional copies are located at Yale Environmental Health and Safety, 135 College Street.

1.2 CHEMICAL HYGIENE RESPONSIBILITIES

Responsibility for chemical health and safety rests at all levels including the:

President of the University, who has ultimate responsibility for chemical hygiene within the institution and must, along with other officers and administrators, provide continuing support for institutional chemical safety.

Department Chair or Director of an administrative unit, who is responsible for chemical hygiene in the department/unit.

Principal Investigator, who has the primary responsibility for chemical hygiene and safety in the laboratory. He/she is responsible for:

- Acquiring the knowledge and information needed to recognize and control chemical hazards in the laboratory;
- Conducting workplace hazard assessments;
• Conducting PPE hazard assessments;
• Selecting and employing laboratory practices, engineering controls, and PPE that reduce the potential for exposure to hazardous chemicals to the appropriate level;
• Informing researchers working in the laboratory of the potential hazards associated with the use of chemicals in the laboratory and instructing them in the safe laboratory practices, adequate controls, and procedures for dealing with accidents involving hazardous chemicals;
• Supervising the performance of the researchers in the laboratory to ensure the required safety and chemical hygiene rules are adhered to;
• Completing required safety training, and ensuring that all lab personnel also complete required safety training;
• Ensuring appropriate controls (engineering and personal protective equipment) are used and are in good working order;
• Obtaining approval, when required, from Yale Environmental Health and Safety prior to purchasing and using particularly hazardous substances;
• Developing an understanding of the current legal requirements regulating hazardous substances used in his/her laboratory;
• Ensuring that chemical hazardous waste is collected, labeled and stored properly;
• Informing visitors entering their laboratory of the potential hazards and safety rules/precautions, including proper work attire and enforcing the use of required personal protective equipment.

**Laboratory worker**, who is responsible for:

• Being aware of the hazards of the materials she/he is around or working with, and handling those chemicals in a safe manner;
• Planning and conducting each operation in accordance with the Yale University chemical hygiene procedures;
• Developing good chemical hygiene habits (chemical safety practices and procedures);
• Wearing the appropriate clothing and required personal protective equipment in the laboratory;
• Reporting unsafe conditions to the Principal Investigator, immediate laboratory supervisor, and/or Yale Environmental Health and Safety;
• Completing all required safety training;
• Collecting, labeling and storing chemical hazardous waste properly;
• Informing visitors entering their laboratory of the potential hazards and safety rules/precautions.

**Chemical Hygiene Officer (Senior Industrial Hygienist)**, who is responsible for:

• Updating the Chemical Hygiene Plan;
• Working with the laboratory community, administrators, Safety Advisors, and others to develop and implement appropriate chemical hygiene policies and practices;
• Providing technical assistance for complying with the Chemical Hygiene Plan, and answering chemical safety questions;
• Overseeing the University wide chemical safety inspection and training programs;
• Assisting Principal Investigators in the selection of appropriate laboratory safety practices and engineering controls for new and existing projects and procedures, together with the Safety Advisors;
Making the final determination for when an exposure assessment is appropriate and conducting or overseeing these assessments;

Knowing the current legal requirements concerning regulated substances;

Investigating or overseeing the investigation of all reported accidents which result in the exposure of personnel or the environment to hazardous chemicals.

**Safety Advisor, Yale Environmental Health and Safety**, who is responsible for:

- Assisting Principal Investigators in the selection of appropriate laboratory safety practices and engineering controls for new and existing projects and procedures, together with the Chemical Hygiene Officer;
- Making an initial determination of the need for an exposure assessment of a laboratory procedure;
- Investigating reported accidents which result in the exposure of personnel or the environment to hazardous chemicals;
- Conducting chemical safety inspections in laboratories in their designated areas and departments;
- Providing technical chemical safety assistance and answering chemical safety questions.

### 1.3 DEFINITIONS

#### 1.3.1 Laboratory Definition

For the purposes of this OSHA standard a laboratory is defined as a facility in which hazardous chemicals (defined below) are handled or manipulated in reactions, transfers, etc. in small quantities (containers that are easily manipulated by one person) on a non-production basis. **Clinical areas in which patients are treated with medication (but no chemical research is conducted), as well as clinical pathology labs, would not be considered a laboratory for the purposes of this plan.**

#### 1.3.2 Hazardous Chemical Definition

The OSHA Laboratory Health Standard defines a hazardous chemical as any element, chemical compound, or mixture of elements and/or compounds which is a physical hazard or a health hazard. The standard applies to all hazardous chemicals regardless of the quantity.

A chemical is a physical hazard if there is scientifically valid evidence that it is a combustible liquid, a compressed gas, an explosive, an organic peroxide, an oxidizer or is pyrophoric, flammable, or reactive.

A chemical is a health hazard if 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 personnel. Classes of health hazards include:
• carcinogens
• reproductive toxins
• irritants
• corrosives
• sensitizers
• neurotoxins
• hepatotoxins
• nephrotoxins
• agents that act on the hematopoietic system
• asphixiants
• agents that damage the lungs, skin, eyes, or mucus membranes

In most cases, the chemical container’s original label will indicate if the chemical is hazardous. OSHA has updated its hazard communication standard to require chemical labels and safety data sheets to be uniform and consistent with global regulations. Starting in 2015, all chemical container labels will comply with this regulation. There will be signal words (Warning, Danger), hazard statements, precautionary statements, and pictograms based on the hazard classification of the chemical. Note that containers of hazardous chemicals acquired or manufactured before 2015 may not contain this standardized information, but will still indicate the contents and hazard warnings. Look for key words like caution, hazardous, toxic, dangerous, corrosive, irritant, carcinogen, etc.

If you are not sure a chemical you are using is hazardous, review the Safety Data Sheet for the substance or contact your supervisor, instructor or your EHS Safety Advisor.

1.4 HAZARD IDENTIFICATION FOR NEWLY SYNTHESIZED CHEMICALS

Some laboratories synthesize or develop new chemical substances during the course of their research. If the composition of the substance is known and will be used exclusively in the laboratory, the researcher must label the substance and determine, to the best of his/her ability, the hazardous properties (e.g. corrosive, flammable, reactive, toxic, etc.) of the substance. This can sometimes be done by comparing the structure of the new substance with the structure of similar materials with known hazardous properties. If the chemical produced is of unknown composition, it must be assumed to be hazardous, and appropriate precautions should be taken.

If a chemical substance is produced for another user outside the University, the laboratory producing the substance is required to provide as much information as possible regarding the identity and known hazardous properties of the substance to the receiver of the material. This should be communicated in the form of a hazard information sheet as illustrated in Appendix E. Contact Yale Environmental Health and Safety if you have questions or would like assistance in meeting this obligation.

1.5 TRAINING & INFORMATION

1.5.1 Chemical Safety Training

All laboratory personnel exposed, or potentially exposed, to hazardous chemicals while performing their laboratory duties must receive information and training regarding the standard, this Chemical Hygiene Plan, and laboratory safety prior to working with these chemicals. Principal Investigators are responsible for the safety in their laboratories and must also receive this information and complete this training. Training sessions arranged by Yale Environmental Health and Safety are held regularly and information about these sessions can be found on the EHS website at ehs.yale.edu. This training is also available on the web at ehs.yale.edu. More information on both the online and live trainings can be found at www.yale.edu/training.

Additional laboratory specific safety training is provided by the Principal Investigator or supervisor.

All laboratory personnel working in the laboratory must receive laboratory chemical safety training prior to beginning work with hazardous chemicals. When performing a non-routine task presenting hazards for which he or she has not already been trained, the supervisor will be responsible for discussing with the researcher the
hazards of the task and any special measures (e.g., personal protective equipment or engineering controls) that should be used. Yale Environmental Health and Safety is available to consult with as necessary. Information on personal protective equipment for specific laboratory tasks is available in the Yale University “Procedure: Selection and Use of Personal Protective Equipment and Attire in Laboratories”. Every laboratory member should know the location and proper use of available protective clothing and equipment, and emergency equipment/procedures. Additional information on protective clothing and equipment is also contained in Section 2.3 of this manual.

1.5.2 Chemical Safety Information Sources

There are numerous sources of chemical safety information on campus. These sources include:
1. the labels found on containers of hazardous chemicals;
2. the substance's Safety Data Sheet;
3. special health and safety reference literature available in several libraries across the campus and on the web;
4. reference literature available from Yale Environmental Health and Safety; and
5. signs, charts, and factsheets available from Yale Environmental Health and Safety and posted in your laboratory.

In addition, your supervisor and your EHS Safety Advisor are available to provide safety information.

Yale University currently subscribes to Chemwatch, a chemical information management software system. Generic and vendor-specific Safety Data Sheets can be easily obtained through this system, as well as labels, single page safety summary information, and emergency information, including first aid and spill response. This system is accessible through the Yale EHS website at http://ehs.yale.edu/forms-tools/chemwatch-msds from any Yale computer.

Yale Environmental Health and Safety also maintains a library of reference materials addressing chemical health and safety issues. EHS also will perform literature searches on health and safety topics upon request or as needed.

1.5.2.1 Container Labeling

All containers of hazardous chemicals must be labeled identifying their contents. Labels on purchased hazardous chemicals must not be removed or defaced except when empty. Secondary working containers that will not be immediately used must also be labeled.

Chemical labels on purchased chemicals are required to provide you with safety information to help you protect yourself while working with this substance. This includes physical and health hazard warnings, protective measures to be used when handling the material, first aid instructions, storage information and procedures to follow in the event of a fire, leak or spill. All chemical labels on chemicals purchased after 2015 are required to contain the information mandated in the new OSHA hazard communication standard. Manufacturers and importers of these chemicals must provide a label that includes a signal word (Danger, Warning), pictogram(s), hazard statement(s), and precautionary statement(s) based on the hazard classification and category of the chemical. This requirement will allow for consistent uniform hazard information on all chemical containers, regardless of manufacturer or supplier.

Read the label each time you use a newly purchased chemical. It is possible the manufacturer may have added new hazard information or reformulated the product since your last purchase, and thus altered the potential hazards you face while working with the product.
All personnel involved in unpacking chemicals are responsible for inspecting each incoming container to insure that it is labeled with the information outlined above. Yale Environmental Health and Safety should be notified if containers do not have proper labels.

1.5.2.2 Safety Data Sheets

A Safety Data Sheet (SDS), formerly called Material Safety Data Sheet (MSDS), is a detailed informational document prepared by the manufacturer or importer of a hazardous chemical which describes the physical and chemical properties of the product. Information included in these data sheets aids in the selection of safe products, helps personnel understand the potential health and physical hazards of the chemical, and describes how to respond effectively to exposure situations. As of June, 2015, all SDSs will be standardized to contain the same information based on the hazard classification and category of the chemical or compound. If you have safety questions regarding a particular chemical contact Environmental Health and Safety or your supervisor.

Generic and vendor-specific Safety Data Sheets can be easily obtained through Chemwatch, an SDS database management system. This system is accessible through the Yale EHS website at [http://ehs.yale.edu/forms-tools/chemwatch-msds](http://ehs.yale.edu/forms-tools/chemwatch-msds) from any Yale computer.

If you do not have web access and want to review a hard copy form of an SDS, Yale Environmental Health and Safety can provide you with one upon request free-of-charge. Your laboratory supervisor may also have SDSs available for the materials commonly used in your laboratory. You can also contact the chemical manufacturer and receive SDSs directly from the supplier.

As of June 2015, all chemical manufacturers and importers must provide updated Safety Data Sheets that conform to the strict requirements of the new hazard communication standard. The new standard provides a single set of harmonized criteria for classifying chemicals according to their health and physical hazards and requires SDS to be in a uniform format, including the 16 section numbers, headings, and associated information below:

- **Section 1: Identification** includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.
- **Section 2: Hazard identification** includes all hazards regarding the chemical; required label elements.
- **Section 3: Composition/information** on ingredients includes information on chemical ingredients; trade secret claims.
- **Section 4: First-aid measures** includes symptoms/effects, acute, delayed; required treatment.
- **Section 5: Fire-fighting measures** lists suitable extinguishing techniques, equipment; chemical hazards from fire.
- **Section 6: Accidental release measures** lists emergency procedures; protective equipment; proper methods of containment and cleanup.
- **Section 7: Handling and storage** lists precautions for safe handling and storage, including incompatibilities.
- **Section 8: Exposure controls/personal protection** lists OSHA’s PELs; ACGIH TLVs; appropriate engineering controls; personal protective equipment (PPE).
- **Section 9: Physical and chemical properties** lists the chemical’s characteristics.
- **Section 10: Stability and reactivity** lists chemical stability and possibility of hazardous reactions.
- **Section 11: Toxicological information** includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.
- **Section 12: Ecological information**
- **Section 13: Disposal considerations**
- **Section 14: Transport information**
- **Section 15: Regulatory information**
- **Section 16: Other information**, includes the date of preparation or last revision.
If you would like additional information concerning the content or use of SDS, contact your supervisor or Yale Environmental Health and Safety.

1.5.2.3 Signs

Prominent signs of the following types must be posted in each laboratory:

- Door ID cards outside each laboratory list the chemical, biological, and radiation hazards for that particular lab, safety equipment available in the lab, restrictions on entering the laboratory, and the names and telephone numbers of the Principal Investigator and other responsible laboratory personnel. These cards are kept updated and are used by emergency responders in the event of an off-hours emergency in the laboratory.
- Signs identifying safety showers, eyewash stations and exits.
- Emergency contact numbers prominently located on or near the laboratory phone.
- Radiation safety or biological safety signs at laboratory doors, sinks, benches, hoods, etc, as appropriate.
- Warnings at areas or equipment where special or unusual hazards exist.
- Laboratory Safety Rules posting.

1.6 CHEMICAL EXPOSURE ASSESSMENT

Regular environmental or personal exposure monitoring of airborne concentrations is not usually warranted or practical in laboratories because chemicals are typically used for relatively short time periods, in small quantities, and/or inside laboratory fume hoods. However exposure monitoring may be appropriate when a highly toxic substance is used regularly or for an extended period of time, or when hazardous chemicals are used outside of a fume hood or used in larger than lab-scale quantities. During annual laboratory safety inspections, Safety Advisors from Yale Environmental Health and Safety will identify these situations during their regular inspections and Industrial Hygienists will perform follow-up exposure assessments as necessary.

Yale Industrial Hygienists will assess exposures to laboratory personnel who suspect and report that they have been overexposed to a toxic chemical in the laboratory or are displaying symptoms of overexposure to toxic chemicals. The assessment may include specific quantitative exposure monitoring. These results and any corresponding recommendations will be sent to the Principal Investigator for the laboratory, the Occupational Health Physician, the affected laboratory personnel, and anyone else deemed appropriate. A copy of the monitoring results will be kept on file in the Yale Environmental Health and Safety Office.

Individual concerns about excessive exposures occurring in the laboratory should immediately be brought to the attention of Yale Environmental Health and Safety and the lab supervisor or Principal Investigator.

1.7 MEDICAL CONSULTATION & EXAMINATION

The University provides researchers who work with hazardous chemicals an opportunity to receive medical attention through the employee health or student medicine programs, including any follow-up examinations which the examining physician determines to be necessary, whenever a researcher:

- develops signs or symptoms associated with excessive exposure to a hazardous chemical used in their laboratory;
- is exposed routinely above the action level (or in the absence of an action level, the applicable OSHA work place exposure limit) for an OSHA regulated substance;
• may have been exposed to a hazardous chemical during a chemical incident such as a spill, leak, explosion or fire; or
• is referred for medical follow up by the Chemical Hygiene Officer.

Individuals with serious or life-threatening emergencies should proceed immediately to the Yale-New Haven Hospital emergency room. An ambulance can be obtained by dialing 911 from any phone. Follow-up medical examination/consultation visits will be handled by the Acute Care physicians at Yale Health or the facility they designate. The appropriate facility to visit can be identified by calling Yale Health Acute Care Department. The appropriate physician at the Yale Health Center will administer non-urgent medical examinations/consultations and medical surveillance.

1.7.1 Medical and Workplace Consultations - Reproductive Toxins

Exposure to certain chemicals may adversely affect the fertility of the parents and may affect the developing fetus during pregnancy. Therefore, anyone working with reproductive toxins or teratogenic agents and planning to conceive a child or are pregnant should consult their Principal Investigator, the Chemical Hygiene Officer, and/or the Department of Employee Health or Student Health as appropriate for opinions regarding risks of exposure and potential exposure control options. The Chemical Hygiene Officer can assess potential exposures and work with the individual and with the Principal Investigator or laboratory supervisor as appropriate, to adjust work practices to minimize any potential risk. The Employee Health or Student Health Physician can discuss the potential risks of exposure as they apply to each particular situation. A list of suspected reproductive toxins and teratogenic agents can be obtained from Yale Environmental Health and Safety.

1.8 LABORATORY SAFETY INSPECTION PROGRAM

The designated Safety Advisor from Yale Environmental Health and Safety conducts, at a minimum, annual safety inspections of all University laboratories handling or storing hazardous materials. As part of these inspections, the EHS Safety Advisor evaluates (1) exposures to personnel (through qualitative assessments); (2) the status of critical control equipment such as fume hoods; (3) the handling and storage of chemicals; (4) use of personnel protective equipment; (5) waste disposal; (6) safety training; and (7) compliance with Federal/State regulation and University policies. More frequent inspections may be established for laboratories working with higher risk materials. Inspection times are arranged in advance with Principal Investigators (PI) and/or lab managers, and PIs receive a written report of the inspection results, along with recommendations and deadlines for improvements, through the Yale EHS Integrator program. The PI or their designee must respond to each recommendation. Department chairs, business managers, safety representatives and/or committees, as directed by the department chairperson, may also receive inspection summary reports for their department.

1.9 RESEARCH PROTOCOL REVIEW

Under some circumstances a particular chemical substance and associated laboratory operation, procedure or activity may be considered sufficiently hazardous to require prior approval from EHS before research begins. In these cases, researchers must complete the Research Protocol Safety Review Form (See Appendix D). For chemicals on the Restricted Item List, EHS will conduct a risk assessment to determine whether the laboratory needs to complete this form. A list of restricted chemicals requiring review and approval prior to purchase is available on our website at http://ehs.yale.edu/regulated-or-highly-hazardous-chemicals.

In addition to the restricted chemicals, researchers must complete this review form if planning on working with hazardous chemicals in a manner outside of the procedures outlined Section 3 of this Chemical Hygiene Plan. This would include using larger volumes and scaling up of experiments.

Researchers anticipating use of materials in a manner requiring review should notify their Safety Advisor and complete the review form in Appendix D. A completed form should be sent to Yale Environmental Health and
Safety. EHS will visit the laboratory, conduct a survey of facility controls, and review the research protocol before approval.

1.10 RESPIRATORY PROTECTION PROGRAM

The University attempts to minimize respiratory exposure to potentially hazardous chemical substances through engineering methods (such as local exhaust ventilation) or administrative controls. It is recognized, however, that for certain situations or operations, the use of these controls may not be feasible or practical. Under these circumstances, while such controls are being instituted, or in emergency situations, the use of personal respiratory protective equipment may be necessary. A sound and effective program is essential to assure that the personnel using such equipment are adequately protected.

The University has a written plan governing the use of respirators on campus. This plan outlines organizational responsibilities for the following respirator program components: exposure assessment; respirator selection; medical approval and surveillance; fit testing; user training; inspection/repair; cleaning/disinfection; and storage. Each of these program components is required by OSHA’s respiratory protection standard (29 CFR 1910.134) in all situations where respirators are used. The Yale University Respiratory Protection Program is available for review on the EHS website at ehs.yale.edu. If you are using a respirator and are not included in the University's respiratory protection program, or have questions concerning the use of respirators or any of the program components, contact your supervisor or Safety Advisor in Environmental Health and Safety.

1.11 RECORDKEEPING

All exposure assessments and occupational medical consultation/examination reports will be maintained in accordance with OSHA's medical records rule (29 CFR 1910.1020). Individuals may obtain copies or read their reports by making a request in writing to Yale Environmental Health and Safety (exposure assessment records) or the Department of Medical Records, Yale Health (occupational medical records).
SECTION 2.0 STANDARD OPERATING PROCEDURES FOR WORKING WITH HAZARDOUS CHEMICALS

2.1 CHEMICAL HANDLING WORK PRACTICES AND PROCEDURES

2.1.1 General Guidelines

Carefully read the label before using a chemical. The manufacturer's or supplier's Safety Data Sheet may also provide special handling information. Be aware of potential hazards existing in the laboratory and of the appropriate safety precautions. Know the location and proper use of emergency equipment, the procedures for responding to emergencies, and the proper methods for storage, transport and disposal of chemicals within the facility.

- Always wear the appropriate personal protective equipment (ppe) as determined during the ppe assessment for the laboratory operation. Use the PPE assessment tool to determine additional PPE requirements for tasks or activities in the lab. At a minimum, safety glasses, lab coat, gloves, clothing that covers the legs and closed-toe solid top shoes are required when working with hazardous materials in the laboratory. Inspect personal protective apparel and equipment for integrity or proper functioning before use.
- Avoid working alone in the laboratory. If you must work alone or in the evening, let someone else know and have them periodically check on you. However, never work with high hazard chemicals or perform high hazard work alone. Notify others in the lab that you will be working with highly hazardous chemicals and plan your work so that this is done during normal working hours.
- Complete required EHS training prior to beginning work. Successful completion of Yale University’s Laboratory Safety Training is required before beginning work with chemicals in a University laboratory.
- Incorporate risk assessments when planning out experiments, and write Standard Operating Procedures before beginning new processes or operations.
- Label all secondary chemical containers with appropriate identification, including squirt bottles and oil or water baths.
- Use only those chemicals for which you have the appropriate exposure controls, such as a chemical fume hood. Always use adequate ventilation with chemicals. Operations using volatile or toxic substances should only be performed in a chemical fume hood.
- Do not dispense more of a hazardous chemical than is needed for immediate use.
- Use hazardous chemicals and all laboratory equipment only as directed or for their intended purpose.
- Inspect equipment or apparatus for damage before adding a hazardous chemical. Do not use damaged equipment.
- Store chemicals in appropriate storage locations. Do not store chemicals on floors and minimize chemical storage outside of chemical cabinets.
- Malfunctioning laboratory equipment (such as a chemical fume hood) should be identified as "out of service" so that others will not inadvertently use it before repairs are made. Contact facilities to repair fume hood as soon as possible.
- If you are doing laboratory work involving hazardous substances that occur continuously or overnight, when no one is present in the laboratory, you need to post a sign on the fume hood or at the door to the lab, indicating your name, contact information, and hazardous materials involved. See Appendix F for the Unattended Operations form.

2.1.2 Personal Hygiene
- Remove contaminated clothing and gloves before leaving laboratory. Never touch door handles, elevator buttons, etc with gloved hands.
- Avoid direct contact with any chemical. Keep chemicals off your hands, face and clothing, including shoes. Never smell, inhale or taste a hazardous chemical. Wash thoroughly with soap and water after handling any chemical.
- Smoking, drinking, eating and the application of cosmetics is forbidden in laboratories where hazardous chemicals are used. (See University Policy on Eating, Drinking, and Smoking in the Laboratories in Appendix B)
- Never pipet by mouth. Use a pipet bulb or other mechanical pipet filling device.

2.1.3 Housekeeping

- Keep floors clean and dry. Keep all aisles, hallways, and stairs clear of all chemicals. Stairways and hallways should not be used as storage areas.
- Keep all work areas, and especially work benches, clear of clutter and obstructions.
- All working surfaces should be cleaned regularly.
- Access to emergency equipment, utility controls, showers, eyewashes, fire extinguishers, and exits should never be blocked.
- Wastes should be kept in the appropriate containers and labeled properly. All hazardous waste containers must be labeled with the full chemical names of the contents and the words “hazardous waste”. Ensure these containers are capped when waste is not being added.

2.1.4 Glassware Safety

Handle and store laboratory glassware with care. Do not use damaged glassware. Borosilicate glassware is recommended for all laboratory glassware except for special experiments that use UV or other light sources. Any glass equipment to be evacuated, such as suction flasks, should be specially designed with heavy walls to withstand pressure. Glass equipment in pressure or vacuum service should be provided with shielding to protect users and other laboratory occupants. Glass vessels at reduced pressure are capable of collapsing violently, either spontaneously (if cracked or weakened) or from an accidental blow. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them with safety netting to contain chemicals or fragments should implosion occur.

2.2 RISK ASSESSMENT AND REVIEW OF SAFETY PROCEDURES

The best way to prevent chemical related accidents and exposures is to design safety into the experiment or protocol. To do this you must understand the potential hazards associated with the chemicals you handle, the equipment used and the procedures followed. This assessment of risk may take several forms depending on the complexity of the experiment and the experience of the researcher, but can be accomplished by following the steps following steps:
- list materials and methods;
- identify hazards;
- select safety measures;
- prepare for mishaps;
- reassess risk.

See Appendix G for a sample chemical protocol risk assessment form that can assist in conducting a successful risk assessment.
Sometimes laboratory workers should not proceed with what seems to be a familiar task. Hazards may exist that are not fully recognized. Certain indicators should cause the researcher to stop and review the safety aspects of their procedure. These indicators include:

- New procedure, process or test even if it is very similar to older practices.
- A change or substitution of any of the ingredient chemicals in a procedure.
- A substantial change in the amount of chemicals used, such as a scale up of experimental procedures. A risk assessment should be completed if the volume of chemicals used increases by 200%.
- A failure of any of the equipment used in the process, especially safeguards such as chemical fume hoods.
- Unexpected experimental results (such as a pressure increase, increased reaction rates, unanticipated byproducts). When an experimental result is different from the predicted, a review of how the new result may affect safety practices should be made.
- Chemical odors, illness that may be related to chemical exposure, or other indicators of a failure in engineered safeguards.

The occurrence of any of these conditions should cause the researcher to pause, evaluate the safety implications of these changes or results, make changes as necessary and proceed cautiously. If needed, call Yale Environmental Health and Safety for assistance.

2.3 PROTECTIVE CLOTHING AND LABORATORY SAFETY EQUIPMENT

Personal protective clothing and equipment should be selected carefully and used after all feasible engineering and administrative controls have been put in place or while such controls are being established. These devices are viewed as less protective than other controls because they rely heavily on each personnel's work practices and training to be effective. The engineering and administrative controls that should always be considered first when reducing or eliminating exposures to hazardous chemicals include:

- **Substitution** of a less hazardous substance or less hazardous equipment or process
- **Scaling down size of experiment**
- **Isolation** of the operator or the process
- **Local and general ventilation** (e.g., use of fume hoods)

A laboratory coat, gloves, protective eyewear, clothing that covers the legs and closed toe shoes are required to be worn in Yale laboratories whenever handling hazardous chemicals. Additional personal protective equipment, such as face shield, utility gloves, aprons, and respirators, may be necessary depending on an assessment of the hazard and operation. The assessment should be made for each laboratory using the PPE assessment tool for laboratory workers. Principal Investigators and supervisors must provide appropriate personal protective equipment to researchers. Refer to the Yale University “Procedure: Selection and Use of Personal Protective Equipment in Laboratories” in Appendix H of this document.

2.3.1 Standard Laboratory Clothing – Appropriate Attire

Where there is no immediate danger to the skin from contact with a hazardous chemical it is still important to wear clothing that minimizes exposed skin surfaces when in the laboratory. Researchers must wear pants or clothing that covers the legs; shorts and short skirts are not acceptable. Closed-toe solid top shoes must be worn in the laboratory at all times. Safety glasses and a laboratory coat are required to be worn whenever working with hazardous materials. Laboratory coats are intended to prevent contact with dirt, chemical dusts and minor
2.3.2 Additional Personal Protective Equipment

Additional personal protective equipment may be required for some types of procedures or with specific substances or operations; such as when larger quantities of corrosives, oxidizing agents or organic solvents are handled. This clothing may include chemically resistant aprons and gloves as well as face shields, goggles, and shoe covers. Refer to the PPE assessment tool to assist in identifying additional required personal protective equipment. Personal protective equipment should never be worn outside the laboratory.

If you are working with substances of high acute or chronic toxicity and wearing washable garments (such as a laboratory coat), evaluate the potential for exposing non-laboratory personnel when laundering. Wear disposable garments if others may be placed at risk during the laundering process. Laundering of lab coats must be done through an approved laundry service or facility – please see the University Buying Guide at http://buying-guide.yale.edu/ for more information.

2.3.3 Gloves

Chemical resistant gloves should be worn whenever handling hazardous chemicals or whenever there is a possibility of contact with hazardous materials. Gloves should be selected on the basis of the materials being handled, the particular hazard involved, and their suitability for the operation being conducted. Before each use, gloves should be checked for integrity. Thin exam-style gloves are most commonly used for laboratory work, and are disposed of in the regular trash after each use. In general, nitrile exam-style gloves offer better chemical protection than either latex or vinyl and all laboratories that use chemicals are strongly encouraged to stock and use nitrile gloves. Latex gloves are discouraged not only because they do not hold up well to many chemicals, but also because of the potential for the user or other lab personnel to develop a sensitization to the latex. Nitrile exam style gloves are generally more chemically resistant than vinyl or latex, but due to the thinness of these gloves it may be recommended to wear double nitrile gloves if contact is possible. Thicker utility style reusable gloves should be worn over thin exam-style if there is a probability of contact with hazardous chemicals. Reusable gloves should be washed prior to removal and replaced periodically, depending on frequency of use and their resistance to the substances handled. The following table offers a general guide to glove selection.

<table>
<thead>
<tr>
<th>Glove Material</th>
<th>Intended Use</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latex exam style</td>
<td>Incidental Contact</td>
<td>• Good for biological and water-based materials</td>
<td>• Poor for organic solvents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• User acceptability</td>
<td>• Hard to detect puncture holes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Latex allergy issues</td>
</tr>
<tr>
<td>Nitrile exam style</td>
<td>Incidental Contact</td>
<td>• Good for solvents, oils, greases, some acids and bases</td>
<td>• May be slightly more expensive than latex</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Clear indication of tears and breaks</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• User acceptability</td>
<td></td>
</tr>
<tr>
<td>Utility style Nitrile – Solvex</td>
<td>Extended Contact</td>
<td>• Good for solvents, oils, greases, some acids and bases</td>
<td>• Not effective for halogenated and aromatic hydrocarbons</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Can be washed and reused</td>
<td></td>
</tr>
<tr>
<td>Neoprene – utility style</td>
<td>Extended contact</td>
<td>• Good for acids, bases alcohols, fuels, peroxides, hydrocarbons, and phenols</td>
<td>• Poor for halogenated and aromatic hydrocarbons</td>
</tr>
</tbody>
</table>
Contact your Safety Advisor in Environmental Health and Safety for personal protection equipment selection assistance or information.

### 2.3.4 Eye Protection

Eye protection is required for all persons present in laboratories where hazardous materials are handled. Some type of eye protection is required to be in a laboratory where hazardous chemicals are used. Prescription eyeglasses may be worn in lieu of safety glasses if not handling hazardous materials in the laboratory, however safety glasses with side shields must be worn when handling hazardous materials. Safety glasses, goggles and goggles with face shield should be worn in the laboratory based upon the physical state, the volume, the operation or the level of toxicity of the chemicals used. Goggles should be worn in situations where bulk quantities of chemicals are handled and chemical splashes to the eyes are possible. Goggles form a liquid proof seal around the eyes, protecting them from a splash. When handling highly reactive substances, chemicals under pressure, or larger quantities of corrosives, poisons, and hot chemicals, goggles with face shield should be worn.

### 2.3.5 Protection Of The Respiratory System

Inhalation hazards can best be controlled using local exhaust ventilation, such as a laboratory fume hood. Respiratory protection can also be used as a secondary means to protect against inhalation hazards, but is not normally required in most research laboratories. Check the label and SDS for information on a substance's inhalation hazard and special ventilation requirements. Take appropriate precautions before using these substances. Controlling inhalation exposures via engineering controls (ventilation) is always the preferred method. As with other personal protective equipment, respiratory protection relies heavily on fit, work practices and training to be effective.

Respirators are designed to protect against specific types of substances in limited concentration ranges. Respirators must be selected based on the specific type of hazard (toxic chemical, oxygen deficiency, etc.), the contaminant's anticipated airborne concentration, and required protection factors.

Types of respiratory protective equipment include:

- Disposable NPR95 or HEPA filter masks (particle-removing respirators)
- Air purifying respirators (vapor, gas and/or particle removing – ½ mask, full face, or powered air purifying (PAPR))
- Atmosphere supplying respirators (air line or SCBA)

Respirators are not to be used except in conjunction with a complete respiratory protection program as required by OSHA. If your work requires the use of a respirator, contact your EHS Safety Advisor and your supervisor or PI. Do not use respiratory protective equipment until you have met all elements of the written Yale University Respiratory Protection Program. Users of respirators must be fitted to the proper size respirator, and thoroughly trained in proper use, maintenance, storage and limitations of this equipment, the nature of the respiratory hazard, and the signals of respirator failure. Medical surveillance to determine the person’s ability to physically wear a respirator must also be conducted. This entails the completion of a medical surveillance questionnaire that is evaluated by the Occupational Health Physician. The Physician will determine whether a physical examination is needed before providing medical clearance to wear the respirator. No one is allowed to wear a respirator on campus without medical clearance from the Occupational Health Physician and without approval and training from Yale Environmental Health and Safety.
Under some circumstances researchers may wish to use respiratory protection equipment for their own comfort or sense of wellbeing, even when there is no recognized hazard or overexposure. Respirator use in these circumstances would be considered “voluntary.” For voluntary users, annual respirator fit testing is not required but we recommend initial fit testing to help ensure proper size selection. Voluntary users of filtering facepiece respirators (N95, N100) are also not required to undergo medical clearances. However, voluntary users of all other respirators are required to complete the medical clearance questionnaire and be medically cleared. See Yale University’s Respiratory Protection Program for more information about respiratory use requirements.

2.3.5 Laboratory Safety Equipment

2.3.5.1 Chemical Fume Hoods

Chemical fume hoods are the primary means of controlling inhalation exposures in the laboratory. Fume hoods are designed to retain vapors and gases released within them, protecting the laboratory worker’s breathing zone from the contaminant. Chemical fume hoods can also be used to isolate apparatus or chemicals that may present physical hazards to researchers. The closed sash on a hood serves as a barrier to fires, flying objects, and chemical splashes or spattering. Yale University standards require that there be a face velocity of 100 fpm (+/- 20%) at the sash opening (18 inches) on most standard fume hoods to adequately control vapors and gases. Some “high performance” fume hoods are designed to operate safely and effectively at lower flow rates. Yale EHS must approve the installation of these high performance hoods and high performance fume hoods must pass ASHRAE 110 testing upon commissioning to verify containment. No fume hood will run with an average face velocity below 100 fpm without approval by EHS. All fume hoods are tested by EHS on an annual basis to verify that this face velocity is maintained.

There are a wide variety of fume hood styles and systems on campus including constant volume, variable air volume, and auxiliary air systems. Many of these systems have been modified with energy-saving setbacks. These setbacks are triggered by a variety of methods including sash position, motion sensors, and room light switches, many in conjunction with time of day.

Many constant air volume systems are on hoods that have a bypass design over the sash. These use higher amounts of energy than other hood systems because they operate on the idea of a constant volume of air being exhausted through the hood, regardless of sash height. Many of the older fume hood systems on campus are bypass hoods with constant air volume systems. With these hoods, the safe sash height is indicated by red arrows. The sash should stay in that position during chemical handling. Those with sash height setbacks for energy savings are marked indicating the setback sash location.

Variable air volume systems use less energy than constant air volume systems because they are designed so that the face velocity stays the same but the volume of air exhausted is lowered as the sash is lowered. The sashes on these hoods should be kept as low as possible when not actively working in the hood. Some of these systems are supplemented with motion sensors that lower flow rates when someone is not working at the hood.

Auxiliary air hoods are constant volume hoods designed for use when it is not feasible to introduce the required makeup air through the room ventilation system. Up to 70% of the exhaust volume can be supplied through an auxiliary air chamber mounted above the hood. These hoods require a separate ducted fan system for the supply of the auxiliary air. There are only a few auxiliary air hood systems like this on campus and these are being phased out.

When using a chemical fume hood keep the following principles of safe operation in mind:

- Keep all chemicals and apparatus at least six inches inside the hood behind the sash.
- Do not use hoods for storage of chemicals and materials.
• Do not block vents and keep equipment and materials raised so to not alter airflow patterns.
• Keep sash as low as possible whenever working in the hood and never work with the sash above the red arrows or sash stoppers.
• Follow the instructions on the “Safe Use of Laboratory Fume Hoods” sticker posted on the hoods.

All work involving volatile or higher hazard chemicals must be conducted inside a chemical fume hood whenever feasible. Contact Environmental Health and Safety with any questions or concerns regarding engineering controls for specific operations.

2.3.5.2 Comment on the Use of Ductless Chemical Fume Hoods

Ductless chemical fume hoods (hoods which recycle air to the laboratory after passing it through a filter) are offered by a variety of manufacturers. Manufacturers claim that these devices are safe and extremely energy efficient because no air is exhausted from the laboratory. These systems typically have a particulate filter and/or a charcoal filter for the removal of organic vapors. These systems must be used with extreme caution. Contact Environmental Health and Safety before purchasing or using one of these ductless hood systems to control chemical exposures. These hoods cannot be purchased without approval from Yale EHS.

The primary safety concern with ductless fume hoods is their filtering mechanism. Charcoal filters are not 100% efficient at removing organic vapors and some organic vapor will always be returned to the laboratory atmosphere. Charcoal filters have a limited ability to adsorb organic vapors and may become saturated quickly. Many ductless fume hoods do not have a method for detecting when the filters are saturated and break through of organic vapors begins. Those that have monitors depend on non-specific chemical sensors that will respond at different concentrations for different substances, and some substances will not be detected. Charcoal filter replacements are expensive and, when operated over several years, may actually be more expensive to operate than ducted hoods.

Applications where ductless chemical fume hoods might be appropriate include the control of particulates, low hazard chemicals, and nuisance odors. Ductless hoods should not be used to protect laboratory workers from toxicologically significant concentrations of hazardous chemicals. Where ductless hoods are installed their use must be monitored to ensure that flow rates and capture effectiveness do not change over time and include operating and work practice procedures, including scheduled filter changouts.

2.3.5.3 Eyewashes and Safety Showers

Whenever chemicals have the possibility of damaging the skin or eyes, an emergency supply of water must be available. All laboratories in which hazardous chemicals are handled and could contact the eyes or skin resulting in injury should have ready access to plumbed, ANSI-approved eyewash stations and safety showers. To ensure easy access and safe use of eyewashes and safety showers:

• Keep all passageways to eyewashes and safety showers clear of any obstacle. This includes temporary storage of supplies, carts, etc.
• Ensure that all laboratory personnel know the location of the nearest eyewashes and safety showers, and how to operate them.
• Eyewashes should be checked routinely by laboratory personnel. Allow them to run for several minutes once per week to clear out the supply lines.
• Shower locations should be checked routinely by laboratory personnel to assure that access is not restricted and that the start chain or lever is within reach.
• The safety showers and eyewashes are tested annually by the Yale Environmental Health and Safety to ensure proper operation and sufficient flow rates.

2.3.5.4 Fire Safety Equipment

Fire safety equipment should be easily accessible to the laboratory must include the appropriate fire extinguisher(s) and may include fire hoses, fire blankets, and automatic extinguishing systems, as determined by the Yale Office of Fire Code and Compliance.

2.4 CHEMICAL PROCUREMENT, DISTRIBUTION AND STORAGE

2.4.1 Chemical Management

Anyone purchasing a hazardous substance must be informed of the proper handling, storage and disposal of this material prior to receipt. It is the responsibility of the Principal Investigator or Supervisor to ensure that the laboratory facilities in which the hazardous materials will be stored and handled are adequate and that those who will handle the substance have received appropriate information and training. Safety Data Sheets may provide some of the necessary information on handling of these hazardous materials. No chemical container should be accepted without an adequate identifying label as outlined in this manual. Chemicals identified on the restricted items list because they are extremely hazardous or are regulated by the Department of Homeland Security (DHS) are flagged for approval by EHS upon purchase and included in a container-level chemical inventory system. All purchase and use of these chemicals requires written safe handling procedures and authorization from EHS.

The list of these chemicals is located at http://ehs.yale.edu/forms-tools/chemicals-requiring-ehs-pre-approval.

2.4.2 Distribution

All containers of hazardous chemicals should be transported in a secondary container such as a chemical carrier. These carriers are commercially available and provide secondary containment as well as "bump" protection. If several bottles must be moved at once, the bottles should be transported on a small cart with a substantial rim to prevent slippage from the cart. Wherever available, a freight elevator should be used to transport chemicals from one floor to another. The stockrooms will not allow purchase of hazardous liquids from the stockroom if there is not have a chemical carrier available to bring it back to the laboratory.

2.4.3 Chemical Storage in the Laboratory

Carefully read the label before storing a hazardous chemical. The SDS will provide any special storage information as well as information on incompatibilities. Do not store unsegregated liquid chemicals in alphabetical order. Do not store incompatible chemicals in close proximity to each other.

Separate hazardous chemicals in storage as follows:

**Solids:**
- oxidizers
- flammable solids (phosphorus, magnesium, lithium)
- water reactives
- others

**Liquids:**
- flammables
- inorganic acids
- organic acids
- caustics
- oxidizers

**Gases:**
- toxic
- oxidizers
- flammable

Once separated into the above hazard classes, chemicals may be stored alphabetically.

Use approved storage containers and safety cans for flammable liquids. It is preferable to store flammable chemicals in flammable storage cabinets. In general, no greater than 10 gallons of flammable liquids may be kept outside of rated flammable storage cabinets or safety cans in any laboratory. *Flammable chemicals requiring refrigeration should be stored only in the refrigerators and freezers specifically designed for flammable storage.*

Hazardous chemicals should not be stored on bench tops, on the floor, or in hoods. Chemicals should also not be stored under sinks, if possible. If separate cabinets are not feasible, chemicals of different chemical classes can be segregated by placing them in trays. Corrosive, flammable or toxic liquids should not be stored above eye level.

Use secondary containers for highly corrosive or toxic chemicals.

Avoid exposure of chemicals while in storage to heat sources (especially open flames) and direct sunlight.

Conduct and review periodic inventories of chemicals stored in the laboratory, and dispose of old or unwanted chemicals promptly in accordance with the EHS hazardous chemical waste program.

Assure all containers are properly labeled with the identity of the contents and any appropriate hazard warnings.

For more information on chemical storage, contact your supervisor or your EHS Safety Advisor.

### 2.4.3.1 Chemical Storage - Chemical Stability

Stability refers to the susceptibility of a chemical to dangerous decomposition. The label and SDS will indicate if a chemical is unstable.

**Special note: peroxide formers** -
Chemicals that can form explosive peroxide crystals on exposure to air require special handling procedures after the container is opened. Some of the chemicals form peroxides that are violently explosive in concentrated solution or as solids, and therefore should never be evaporated to dryness. Others are polymerizable unsaturated compounds and can initiate a runaway, explosive polymerization reaction. All peroxidizable compounds should be stored away from heat and light. They should be protected from physical damage and ignition sources. All containers peroxide formers should be dated upon receipt and upon opening. No peroxide forming compound should be kept for longer than one year after opening. See Section 3.2, Highly Reactive Chemicals and High Energy Oxidizers for additional information on storage limitations and Appendix I for examples of materials which may form explosive peroxides.

For additional information on chemical stability, contact your supervisor or your EHS Safety Advisor.
2.4.3.2 Chemical Storage - Incompatible Chemicals
Certain hazardous chemicals should not be mixed or stored with other chemicals because a severe reaction can take place or an extremely toxic reaction product can result. The label and SDS will contain information on incompatibilities and should always be consulted. See Appendix J for examples of incompatible chemicals.

2.5 CHEMICAL SPILLS & ACCIDENTS

2.5.1 General Information

Try to anticipate the types of chemical spills that can occur in the laboratory and keep the necessary equipment (spill kits and personal protective equipment) to respond to a minor spill. Learn how to safely clean up minor spills of the chemicals used regularly. An SDS contains special spill clean-up information and should also be consulted. Chemical spills should only be cleaned up by trained, knowledgeable and experienced personnel.

If the spill is too large to handle, requires respiratory protection, is a threat to personnel, students or the public, or involves a highly toxic or reactive chemical, call for assistance immediately:

Yale Environmental Health and Safety - Hazardous Materials Emergency Response 203-785-3555

Yale Environmental Health and Safety is equipped to handle most spills that can occur at the University. If there is the slightest doubt regarding how to proceed, call for assistance.

The following compounds are very hazardous. **You should not clean them up yourself, no matter how small the spill:**

- Aromatic amines
- Hydrazine
- Bromine
- Organic Halides
- Carbon disulfide
- Nitriles
- Cyanides
- Nitro compounds

2.5.2 Minor Chemical Spill

Trained workers can clean-up most minor spills without direct EHS assistance if they are comfortable doing so and fully understand the hazards of the spilled material and methods to protect themselves. However, if there are any concerns or questions about the ability to safely clean the spill, EHS should be contacted.

- Alert people in immediate area and restrict access to spill location.
- Avoid vapors or dusts from spill. If dry/powder material is spilled, minimize air disturbances and drafts. However, if spill involves a volatile liquid, increase ventilation if possible.
- Confine liquid spills with absorbent materials to minimize spread.
- Identify the materials involved, quantity, and specific location of the spill. Review Chemwatch SDS [http://ehs.yale.edu/forms-tools/chemwatch-msds](http://ehs.yale.edu/forms-tools/chemwatch-msds) for additional information. Evaluate hazard(s) and address personal contamination/injury. Summon any additional emergency services needed.
- To clean up minor chemical spill, wear basic protective equipment appropriate to hazard – if respiratory protection is needed, the incident is NOT minor. Refer to PPE assessment tool.
- Use appropriate kit to absorb or neutralize spilled material. Work from perimeter inwards. Collect residue with scoop, dust pan, or cardboard, place in heavy plastic bag or other receptacle, affix hazardous waste label describing contents, and contact Yale EHS for waste pick-up.
- Clean spill area with soap and water.
- If floor finish has been damaged, contact Custodial Services.
2.5.3 Major Chemical Spill

- Attend to injured or contaminated persons and remove them from exposure if safe to do so.
- Alert people in the laboratory to evacuate.
- If spilled material is flammable, turn off ignition and heat sources. If you can do so safely, place spill cleanup material over spill to keep substance from volatilizing.
- Close doors to affected area.
- Call 24 hour Yale Hazardous Materials Emergency Response number (203-785-3555) to report the incident and request assistance.
- Have a person with knowledge of the incident and laboratory available to answer questions from responding emergency personnel.

2.5.4 Small Mercury Spills

- Do not use a domestic or commercial vacuum cleaner.
- Contact Environmental Health and Safety if you have a mercury spill that exceeds the quantity found in a normal laboratory thermometer, or if you require assistance in cleaning up any quantity of spilled mercuryl.
- Use a disposable pipette to pick up mercury droplets.
- Cover small droplets in inaccessible areas with powdered sulfur or zinc.
- Place residue in a labeled container and call Yale Environmental Health and Safety for disposal information.
- EHS can also monitor mercury vapor levels in the room to verify mercury levels are safe after cleanup.

2.5.5 Alkali Metal Spills

- Smother with powdered graphite, sodium or calcium carbonate or "Met-L-X", call for assistance.

2.6 PERSONAL CONTAMINATION AND INJURY

2.6.1 General Information

- Know the locations of the nearest emergency safety shower, eye wash station, and fire extinguisher.
- Report all incidents and injuries to your supervisor.
- Do not move an injured person unless they are in further danger from inhalation or skin exposure.
- Get medical attention promptly by dialing:
  
<table>
<thead>
<tr>
<th>Service</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>University Police (ambulance)</td>
<td>911</td>
</tr>
<tr>
<td>Yale Health Acute Care (minor medical)</td>
<td>203-432-0123</td>
</tr>
<tr>
<td>Yale EHS Hazardous Materials Emergency Response</td>
<td>203-785-3555</td>
</tr>
</tbody>
</table>

2.6.2 Chemicals Spills to the Body

- Remove any contaminated clothing or footwear.
- Immediately flood the affected body area with cool water for at least 15 minutes using the nearest emergency shower.
- Call or have a co-worker call for medical assistance by dialing 911.
- Contact EHS emergency (203-785-3555) for assistance, to clean up any hazardous materials spill, and to report incident.
Obtain SDS or other information source for chemical involved and provide to the appropriate emergency responder and health care provider.

It should be noted that some chemicals (e.g., phenol, aniline) are rapidly adsorbed through the skin. If a large enough area of skin is contaminated an adverse health effect (systemic toxicological reaction) may occur immediately to several hours after initial exposure depending on the chemical. In general, if more than a few square inches of skin area has been exposed to a hazardous chemical, seek medical attention after washing the material off the skin.

2.6.3 Chemical Splash in the Eye

- Flush the eyeball(s) and inner surface of eyelid(s) with plenty of water for at least 15 minutes. Using a nearby safety eyewash, forcibly hold eyelids open to ensure effective rinsing.
- Call or have a co-worker call for medical assistance.
- Check for and remove contact lenses if possible.
- Get medical attention promptly. Obtain SDS or other information source for chemical involved and provide to the appropriate emergency responder and health care provider. Contact Yale EHS at 203-785-3555 for assistance and to report exposure.

2.6.4 Ingestion of Hazardous Chemicals

- Call or have a co-worker call for medical assistance.
- Identify chemical ingested. If available, save container for reference.
- Do not induce vomiting or drink water or other liquids unless instructed to do so by medical responders.
- Cover victim for warmth/prevent shock. Remain with victim.
- Provide the ambulance crew and physician with as much information about the material ingested as possible. If available, send the container, container label, or product Safety Data Sheet with the emergency responders.
- Contact Yale EHS at 203-785-3555 for assistance and to report exposure.

2.6.5 Inhalation of Smoke, Vapors and Fumes

Anyone overcome with smoke or chemical vapors or fumes should be removed to uncontaminated air and treated for shock, if it is safe to do so. Do not enter the area if you believe a life threatening condition still exists - oxygen depletion, explosive vapors or highly toxic gases (ex: cyanide gas, hydrogen sulfide, nitrogen oxides, carbon monoxide, arsine, phosphine)

- Remove exposed person to uncontaminated air and treat for shock (sit or lie down, cover to keep warm, remain with victim).
- Call or have a co-worker call 911 for medical assistance.
- Contact Yale EHS at 203-785-3555 for assistance and to report exposure.
- Get medical attention promptly.

2.6.6 Organo-Heavy Metal Compounds

Many organic forms of heavy metals (e.g., dimethyl mercury, tetraethyl lead) are extremely toxic and highly permeable to most common personal protective equipment. If you or a co-worker suspect direct contact with these compounds, follow the procedures listed for Chemical Spills on the Body, and immediately obtain professional medical attention.
2.6.7 Cyanide

Cyanide antidote kits are available at the YNHH emergency room – which is where cyanide victims should be directed. Immediately summon emergency medical assistance, indicating that the exposure involved cyanide. Follow the steps outlined above for chemical exposures. However, in the event of inhalation or ingestion exposure to cyanide, DO NOT give mouth-to-mouth resuscitation as this may cause serious exposure to the rescuer.

2.6.8 Hydrogen Fluoride/Hydrofluoric Acid

Hydrogen fluoride and hydrofluoric acid cause severe, deeply penetrating burns to the skin, eyes, and lungs. Although concentrated forms of these compounds are readily perceived by a burning sensation, more dilute forms are often imperceptible for many hours. This potential time delay between exposure and treatment can lead to insidious and difficult-to-treat burns. Calcium gluconate gel is an effective treatment for hydrofluoric acid exposure. Every laboratory and location where HF is used or stored should have a tube of calcium gluconate readily available and a bottle of gluconate eyewash solution. The Office of Environmental Health and Safety currently purchases and distributes these free-of-charge to all HF user locations. Please contact your Safety Advisor or Environmental Health and Safety if you work with HF and need calcium gluconate.

2.6.8.1 Skin Exposure to HF
- Remove any contaminated clothing or footwear.
- Immediately flood the affected body area with cool water for at least 15 minutes (limit to 5 minutes if calcium gluconate gel is available).
- Call or have a co-worker call for medical assistance.
- Gently rub calcium gluconate ointment onto the affected area, and continue to apply until medical response arrives.
-Await emergency medical responders, informing them and all others that the exposure involved hydrogen fluoride/hydrofluoric acid.

2.6.8.2 Eye Exposures to HF
- Immediately flush eyes for at least 5 minutes with cool flowing water. Hold the eyelids open and away from the eye during irrigation to allow thorough flushing of the eyes. If sterile 1% calcium gluconate solution is available, washing may be limited to 5 minutes, after which the 1% calcium gluconate solution should be used repeatedly to irrigate the eye.
- Contact 911 and inform dispatcher that eye exposure involves HF.
- Continue to rinse in eyewash, or with 1% calcium gluconate solution, until EMS arrives.

2.6.8.3 Inhalation Exposures to HF
- Follow the same procedures outlined earlier for chemical splashes to the eye and inhalation exposures (e.g., flush eyes with plenty of cool tap water, move inhalation exposure victim to clean air).
- Use the Calgonate emergency eyewash solution containing 1% calcium gluconate, if available.
- Call or have a co-worker call for medical assistance.
- Await emergency medical responders, informing them and all others that the exposure involved hydrogen fluoride/hydrofluoric acid.

2.7 FIRE AND FIRE RELATED EMERGENCIES

If you discover a fire or fire-related emergency such as abnormal heating of material, a flammable gas leak, smoke, or odor of burning, immediately follow these procedures:
- Notify the Fire Department by dialing 911
- Activate the building alarm (fire pull station).
• Isolate the area by closing windows and doors and evacuate the building.
• Shut down equipment in the immediate area, if possible.
• If trained to do so, use a portable fire extinguisher to:
  ‣ assist oneself to evacuate;
  ‣ assist another to evacuate; and
  ‣ control a small fire, if possible.

Provide the fire/police teams with the details of the problem upon their arrival. Special hazard information you might know is essential for the safety of the emergency responders.

If the fire alarms are ringing in your building:

• You must evacuate the building and stay out until notified to return.
• Move upwind from the building and stay clear of streets, driveways, sidewalks and other access ways to the building.
• If you are a supervisor, try to account for lab personnel, keep them together and report any missing persons to the emergency personnel at the scene.

2.8 CHEMICAL WASTE DISPOSAL PROGRAM

Laboratory chemical waste must be handled according to the University's policy and management guidelines outlined in the EHS manual -Management of Hazardous Wastes – A Policy and Procedure Manual – Chemical Waste Section. The University's waste management practices are designed to ensure maintenance of a safe and healthful environment for laboratory personnel and the surrounding community without adversely affecting the environment. This is accomplished through regular removal of chemical waste from University facilities and disposal of these wastes in compliance with local, state, and federal regulations. The manual provides laboratory personnel with specific guidance on how to identify, handle, collect, segregate, store, tag and dispose of chemical waste appropriately. For additional information on Yale's chemical waste management program contact your EHS Safety Advisor.
3.1 FLAMMABLE LIQUIDS

3.1.1 General Information

Flammable liquids are among the most common of the hazardous materials found in laboratories. They are usually highly volatile (have high vapor pressures at room temperature) and their vapors, mixed with air at the appropriate ratio, can ignite and burn. By definition, the lowest temperature at which they can form an ignitable vapor/air mixture (the flash point) is less than 100°F. For many common laboratory solvents such as ether, acetone, toluene, and acetaldehyde, the flash point is well below room temperature. As with all solvents, their vapor pressure increases with temperature and, therefore, as temperatures increase they become more volatile and more hazardous.

For a fire to occur, three distinct conditions must exist simultaneously: (1) the concentration of the vapor must be between the upper and lower flammable limits of the substance (the right fuel/air mix); (2) an oxidizing atmosphere, usually air, must be available; and (3) a source of ignition must be present. Removal of any of these three conditions will prevent the start of a fire. Flammable liquids may form flammable mixtures in either open or closed containers or spaces (such as refrigerators), when leaks or spills occur in the laboratory, and when heated.

Strategies for preventing ignition of flammable vapors include removing all sources of ignition, or maintaining the concentration of flammable vapors below the lower flammability limit by using local exhaust ventilation such as a fume hood. The former strategy is more difficult because of the numerous ignition sources in laboratories such as open flames, hot surfaces, operation of electrical equipment, and static electricity.

The concentrated vapors of flammable liquids are usually heavier than air and can travel away from a source for a considerable distance across laboratories, into hallways, and down elevator shafts or stairways. If the vapors reach a source of ignition a flame can result that may flash back to the source of the vapor.

The danger of fire and explosion presented by flammable liquids can usually be eliminated or minimized by strict observance of safe handling, dispensing, and storing procedures.

3.1.2 Special Handling Procedures – See SOP in Appendix K

While working with flammable liquids you should always wear gloves, protective glasses or goggles, long sleeved lab coats and closed toe shoes. Long pants or clothing that covers the legs should always be worn in any laboratory. Wear tight-fitting chemical goggles if dispensing solvents or performing an operation that could result in a splash to the eyes.

Flammable liquids should always be handled in a chemical fume hood or under some other type of local exhaust ventilation. When dispensing flammable solvents into small storage containers, use metal or plastic containers or safety cans and avoid glass containers. If splash risk is high wear a face shield in addition to goggles.

Make sure that metal surfaces or containers through which flammable substances are flowing are properly grounded, discharging static electricity. Free flowing liquids generate static electricity that can produce a spark and ignite the solvent.
Larger quantities of flammable liquids must be handled in areas free of ignition sources (including spark emitting motors and equipment) using non-sparking tools. Remember that vapors are heavier than air and can travel to a distant source of ignition.

Never heat flammable substances by using an open flame. Instead use any of the following heat sources: steam baths, water baths, oil baths, heating mantles or hot air baths. Do not distill flammable substances under reduced pressure.

Store flammable substances away from ignition sources. Flammable liquids should be stored inside rated flammable storage cabinets. If no flammable storage cabinet is available, small quantities may be stored in a cabinet under the hood or bench. Five-gallon containers should only be stored in a storage cabinet that is rated for flammables.

The total volume of flammable liquids kept outside of rated flammable cabinets and safety cans should not exceed 10 gallons at any one time in the laboratory. Never store containers of flammable liquids or other hazardous chemicals on the floor.

Oxidizing and corrosive materials should not be stored in close proximity to flammable liquids. Flammable liquids should never be stored or chilled in domestic refrigerators and freezers but in units specifically designed for this purpose. It is acceptable to store or chill flammables in ultra-low temperature units.

If flammable liquids will be placed in ovens make sure they are appropriately designed for flammable liquids (no internal ignition sources and/or vented mechanically). Make sure the autoignition temperature of the solvent is above the oven temperature or its internal elements.

### 3.2 HIGHLY REACTIVE CHEMICALS & HIGH ENERGY OXIDIZERS

#### 3.2.1 General Information

Highly reactive chemicals include those which are inherently unstable and susceptible to rapid decomposition as well as chemicals which, under specific conditions, can react alone or with other substances in a violent uncontrolled manner, liberating heat, toxic gases, or leading to an explosion. Because reaction rates increase dramatically as the temperature increases, if heat evolved from a reaction is not dissipated the reaction can accelerate out of control and could result in injuries or costly accidents.

Air, light, heat, mechanical shock, water, and certain catalysts can cause violent decomposition of some highly reactive chemicals. Examples include hydrogen and chlorine which can react explosively in the presence of light. Alkali metals, such as sodium, potassium and lithium will react violently with water liberating hydrogen gas. Examples of shock sensitive materials include acetylides, azides, organic nitrates, nitro compounds, and many peroxides.

**Organic peroxides** are a special class of compounds that have unusual stability problems, making them among the most hazardous substances normally handled in the laboratories. As a class, organic peroxides are low powered explosives. Organic peroxides are extremely sensitive to light, heat, shock, sparks, and other forms of accidental ignition; as well as to strong oxidizing and reducing materials. All organic peroxides are also highly flammable. Examples of organic peroxides found in laboratories include concentrated benzoyl peroxide and methyl ethyl ketone peroxide (MEKP).

**Peroxide formers** can form reactive peroxides during storage and especially after exposure to the air (once opened). Peroxide forming substances include: aldehydes, cyclic ethers, compounds containing benzylic hydrogen atoms, compounds containing the allylic structure (including most alkenes), vinyl and vinylidine compounds.
3.2.2 Special Handling Procedures for Highly Reactive Compounds – See Specific SOPs in Appendices L and M

Before working with a highly reactive material or high energy oxidizer, review available reference literature to obtain specific safety information. The proposed reactions should be discussed with the principal investigator or your supervisor. An SOP needs to be developed, reviewed and available for work involving these materials.

When working with highly reactive compounds and high energy oxidizers always wear the following personal protection equipment: long sleeved lab coats, gloves, closed toe shoes and protective glasses/goggles. Long pants or clothing that covers the leg to the ankles must always be worn when working with hazardous materials in the laboratory. A face shield or body shield should be worn in addition to protective eyewear based on the scale and nature of the material and of the reaction. Refer to the PPE assessment tool to determine the appropriate personal protective equipment for your operation.

Minimize the amount of highly reactive material involved in any experiment; the smallest amount sufficient to achieve the desired result should be used. Scale-ups should be handled with great care, giving consideration to the reaction vessel size and cooling, heating, stirring and equilibration rates, and a separate SOP conducted for all scale-ups. A new risk assessment needs to be conducted for any scale up of procedures involving highly reactive material.

Keep only the minimum amount of highly reactive compounds stored in the laboratory. The key to safely handling reactive chemicals is to keep them isolated from the substances that initiate their violent reactions. Unused reactive compounds should never be returned to their original container but should be discarded as hazardous waste.

Do not work alone. All operations where highly reactive and explosive chemicals are used should be performed during the normal work day or when other laboratory personnel are available either in the same laboratory or in the immediate area.

Perform all manipulations of highly reactive or high energy oxidizers inside a chemical fume hood. Some factors to be considered in judging the adequacy of the hood include its size in relation to the reaction and required equipment and the ability to fully close the sash. Keep the sash positioned between yourself and the highly reactive material, and use a blast shield as necessary.

Handle highly reactive chemicals away from the direct light, open flames, and other sources of heat. Oxidizing agents should only be heated with fiberglass heating mantles or sand baths.

Make sure that the reaction equipment is properly secured. Reaction vessels should be supported from beneath with tripods or lab jacks. Use shields or guards which are clamped or secured. If possible use remote controls for controlling the reaction, such as cooling, heating and stirring controls. These should be located outside the shield or hood.

Store highly reactive chemicals and high-energy oxidizers in closed cabinets segregated from the materials with which they react, inside secondary containment. Do not store these substances above eye level or on open shelves.

Never distill substances contaminated with peroxides. Never use a metal spatula with peroxides, since contamination by metals can lead to explosive decompositions.
Labels on peroxide forming substances should contain the date the container was received, first opened and the initials of the person who first opened the container. At a minimum, peroxide forming substances that have been opened for more than one year should be discarded. See section 3.2.3 for storage information for specific peroxide forming chemicals.

Store peroxides and peroxide forming compounds in a cool location away from light. If you use a refrigerator make sure it is rated for the storage of flammable substances. Store light-sensitive compounds in the light-tight containers. Store water-sensitive compounds away from water sources.

Handle shock sensitive substances gently, avoid friction, grinding, and all forms of impact. Glass containers that have screw-cap lids or glass stoppers should not be used with shock sensitive materials.

Shock sensitive materials should be discarded after one year if in a sealed container and within six months of opening unless an inhibitor was added by the manufacturer.

Perchloric acid is a high energy oxidizer that can volatilize and potentially condense in the ventilation system, leaving highly reactive perchlorate crystals which can be a serious fire and explosion hazard. Perchlorates can form if the perchloric acid is highly concentrated (≥72%) or if any concentration is heated above room temperature. Inorganic oxidizers such as perchloric acid can react violently with most organic materials and must be stored and used separately from organic materials. Any handling and work with large volumes of perchloric acid, or with highly concentrated or heated perchloric acid can only be conducted in a dedicated perchloric acid fume hood with a functioning wash-down system. Please notify Yale Environmental Health and Safety if you are planning on heating perchloric acid or using highly concentrated or large volumes.

3.2.3 Special Procedures for Peroxide Forming Compounds – See SOP in Appendix N

Some common laboratory chemicals can undergo autoxidation to form unstable and potentially dangerous peroxide by-products. The reaction can be initiated by light, heat, introduction of a contaminant, or the loss of an inhibitor. Some chemicals have inhibitors such as BHT (2,6-di-tert-butyl-4-methyl phenol) hydroquinone and diphenylamine to slow peroxide formation. Most of the organic peroxide crystals that are formed are sensitive to heat, shock, or friction, and their accumulation in laboratory reagents and fume hood exhaust ductwork has resulted in explosions. Therefore, it is important to identify and control chemicals that may form potentially explosive peroxides.

Class A peroxide formers are chemicals that spontaneously form peroxides on exposure to air without concentration or evaporation. These materials should be disposed of within three months of opening. Isopropyl ether is an example of a Class A peroxide former. Class B peroxide formers may form peroxides upon concentration by evaporation or distillation and should be disposed of within one year of opening their containers or by the expiration date indicated on the manufacturer’s label. Diethyl ether, tetrahydrofuran, and dioxane are common examples or Class B peroxide formers. Class C peroxide formers are unsaturated monomers that autopolymerize as a result of peroxide accumulation if inhibitors have been removed or are depleted, and should be disposed of within one year of opening. Styrene and ethyl acrylate are examples of Class C peroxide formers. Common peroxide forming compounds that are used in laboratories are listed in the table in Appendix O.

3.2.4 Special Handling Procedures for Pyrophoric Chemicals

Pyrophoric and water reactive materials can ignite spontaneously on contact with air, moisture in the air, oxygen, or water. Failure to follow proper handling procedures can result in fire or explosion with the potential to cause significant damage to facilities, serious injuries and death. Anyone working with pyrophoric chemicals must follow the guidelines in the Yale Pyrophoric Materials Handling Policy. Purchases of pyrophoric chemicals are flagged as Restricted and are routed to EHS for approval.
Basic rules for working with pyrophoric chemicals are Yale University are as follows:

Clothing and Personal Protective Equipment Requirements: Non-synthetic clothing should be worn when working with pyrophoric chemicals. In addition, always wear a flame resistant lab coat when working with any material that can ignite in air, including pyrophoric liquids and alkali metals. For larger volumes, flame-resistant “flight gloves” should be worn. These are not chemically resistant but could be worn over exam style nitrile gloves. The flame resistant lab coats and flight gloves are available in the Chemistry Department stockroom and are also available through Yale EHS. EHS has also provided a flame resistant lab coat to each laboratory that uses pyrophoric chemicals. The PPE assessment tool should be used to determine the appropriate personal protective equipment requirements. Contact EHS for more information.

Never work alone when handling pyrophoric or highly reactive materials. Always let others in the laboratory know when you are working with these materials, and try to schedule your work during normal working hours.

Before working with a pyrophoric material, review available reference literature to obtain specific safety information. The proposed reactions should be discussed with your Principal Investigator or your supervisor. An SOP should be developed, reviewed and available for work involving these materials.

Always minimize the amount of material involved in the experiment; the smallest amount sufficient to achieve the desired result should be used. Scale-ups should be handled with great care, giving consideration to the reaction vessel size and cooling, heating, stirring and equilibration rates. A new risk assessment needs to be conducted for any scale up of procedures involving pyrophoric chemicals.

Look to use materials that are less reactive whenever possible.

Only work with pyrophoric chemicals in areas where there is an ANSI approved eyewash and safety shower nearby. Be sure to know where they are located and the procedures to follow in the event of an emergency prior to beginning work.

Be sure to have the appropriate fire extinguisher nearby before beginning work with pyrophoric materials. Note that Class D extinguishers are necessary for fires involving alkali metals, but dry chemical extinguishers (ABC, BC) are appropriate for fires involving liquid organolithium reagents.

3.2.4.1 Additional Special Handling Procedures for Organolithium Compounds

Organolithium compounds are commonly used for organic chemical synthesis. Anyone planning on working with organolithium compounds must also follow additional requirements outlined below.

- Complete and receive TMS credit for the online training “Working Safely with Organolithium Compounds” linked here [http://ehs.yale.edu/training/organolithium-compounds-training](http://ehs.yale.edu/training/organolithium-compounds-training)
- Dispose as hazardous waste within 1 month of opening.
- Only purchase the amount that you plan to use for each experiment. Any purchase over 100 ml bottle will need to be authorized and approved by Yale EHS.
- Review the Aldrich technical bulletins AL-134 “Handling Air-Sensitive Reagents” and AL-164 “Handling Pyrophoric Reagents”.
- Work inside the fume hood with the horizontal sash positioned in front of you to protect you from any splash that may occur. If your fume hood does not have a horizontal sash, use a splash guard positioned in front of the bottle when drawing the liquid into the syringe.
3.3 COMPRESSED GASES

3.3.1 General Information

Compressed gases present both a physical and a potential chemical hazard, depending on the particular gas. Gases contained in cylinders may be from any of the hazard classes described in this section (flammable, reactive, corrosive, or toxic). Because these are compressed gases, concentrations in the laboratory can increase instantaneously if leaks develop at the regulator or piping systems, creating the potential for a hazardous chemical exposure or a fire/explosion. Even inert gases such as nitrogen or argon can displace room oxygen if accidentally released. Often there is little or no indication that leaks have occurred or are occurring. In addition, the large amount of potential energy resulting from compression of the gas makes a compressed gas cylinder a potential rocket or fragmentation bomb if the tank or valve is physically broken.

3.3.2 Special Handling Procedures

Wear safety glasses, gloves, long sleeved lab coat, long pants and closed toe shoes when handling compressed gases. Refer to the PPE assessment tool for specific personal protective equipment requirements for your operation.

The contents of any compressed gas cylinder should be clearly identified. No cylinder should be accepted for use that does not legibly identify its contents by name. Color coding is not a reliable means of identification.

Carefully read the label before using or storing compressed gas. The SDS will provide additional hazard information.

All gas cylinders should be clearly marked with appropriate tags indicating whether they are in use, full, or empty.

All gas lines leading from a remote compressed gas supply should be clearly labeled identifying the gas and the laboratory served.

All cylinders, including empty ones, must be stored securely with the regulator removed and valve protection cap in place. Use suitable racks, straps, chains or stands to support cylinders, and keep them away from heat sources. Store as few cylinders as possible in your laboratory.

Transport gas cylinders in carts one or two at a time only while they are secured and capped. Do not move gas cylinders by rolling them.

Place gas cylinders in such a way that the cylinder valve is accessible at all times. The main cylinder valve should be closed as soon as the gas flow is no longer needed. Do not store gas cylinders with pressure on the regulator.

Use the wrenches or other tools provided by the cylinder supplier to open a valve if necessary. Pliers should not be used to open a cylinder valve or attach a regulator or pigtail.

Use a leak check solution to detect leaks. Leak test the regulator, pigtail connections, and any piping system after performing maintenance or making modifications which could affect the integrity of the system. Always use a leak check solution that is approved for oxygen whenever leak checking oxygen or nitrous oxide cylinders.

Oil or grease on the high pressure side of an oxygen cylinder can cause an explosion. Do not lubricate an oxygen regulator.
Cylinders of toxic, corrosive or reactive gases should be purchased in the smallest quantity possible and stored/used in an approved ventilated gas cylinder storage cabinet, fume hood or under other approved local exhaust ventilation.

Flammable gases should be stored in a ventilated gas cabinet if possible. Be sure to check with the Office of Fire Code Compliance (OFCC) and EHS if there are multiple flammable gas cylinders in your laboratory.

In general, avoid the purchase of lecture bottles. These cylinders are not returnable and it is extremely difficult and costly to dispose of them. Small refillable cylinders may be an available alternative, or use the smallest returnable sized cylinder. Any purchase of lecture bottles must be approved by Yale Environmental Health and Safety.

Keep regulators bagged and safe from damage when not in use. Do not use any regulator that appears damaged, dirty, or in otherwise questionable condition. Regulators greater than 10 years old in storage should be not be used unless they have been tested and certified.

Use only Compressed Gas Association standard combinations of valves and fittings for compressed gas installations. Never use a regulator adaptor. The CGA number should be visible on all regulators. Do not use any regulator that does not have a CGA number marking. The following table lists the CGA connections for gases commonly used in laboratories. A complete list of gases and their corresponding CGA numbers is available from your gas supplier and from EHS.

<table>
<thead>
<tr>
<th>Compressed Gas</th>
<th>CGA number</th>
<th>Compressed Gas</th>
<th>CGA number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>580</td>
<td>Freon</td>
<td>660</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>320</td>
<td>Helium</td>
<td>580</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>350</td>
<td>Hydrogen</td>
<td>350</td>
</tr>
<tr>
<td>Chlorine</td>
<td>660</td>
<td>Hydrogen chloride</td>
<td>330</td>
</tr>
<tr>
<td>Ethane</td>
<td>350</td>
<td>Nitrogen</td>
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</tr>
<tr>
<td>Ethylene</td>
<td>350</td>
<td>Oxygen</td>
<td>540</td>
</tr>
</tbody>
</table>

### 3.3.3 Special Precautions for Hydrogen

Hydrogen gas has several unique properties that make it a dangerous with which to work. It has an extremely wide flammability range (LEL 4%, UEL 74.5%) and is easier to ignite than most other flammable gases. Unlike most other gases, hydrogen's temperature increases during expansion. If a cylinder valve is opened too quickly the static charge generated by the escaping gas may cause it to ignite. Hydrogen burns with an invisible flame. Caution should therefore be exercised when approaching a suspected hydrogen flame. Cast iron pipes and fittings must never be used with hydrogen because hydrogen embrittlement can weaken carbon steel. Precautions associated with other flammable substances identified above also apply to Hydrogen.

### 3.3.4 Special Requirements for Highly Toxic or Flammable Gases

Toxic and flammable gases are restricted chemicals and require EHS approval prior to purchase – See list below. Many of these gases are also regulated under the Department of Homeland Security. See Section 3.7. Toxic, corrosive and pyrophoric gases must be used under local exhaust ventilation, either in a ventilated gas cabinet or inside a chemical fume hood. A continuous toxic gas monitoring system may also be necessary in laboratories where these gases are used or stored. A written SOP is required for laboratory procedures involving toxic, corrosive, pyrophoric, and flammable gases.
See Appendix P for a list of toxic and flammable gases that require EHS approval prior to purchase and use.

### 3.4 CORROSIVE CHEMICALS

#### 3.4.1 General Information

As a health hazard, corrosive substances can rapidly destroy or alter living tissue by chemical action at the site of contact. Symptoms of exposure for inhalation of corrosive vapor or mist include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea, and vomiting. For eyes, symptoms include pain, tearing, and blurring or loss of vision. For skin, symptoms may include reddening, pain, inflammation, blistering and burns. As a physical hazard, corrosive substances may corrode materials they come in contact with and may be highly reactive with other substances. It is important to review information regarding materials they corrode, and their reactivity with other substances, as well as information on health effects.

If you suspect you may have been exposed to a corrosive chemical, flush the exposed area with water for at least fifteen minutes at an approved emergency eyewash or safety shower, and immediately seek medical treatment.

**Strong acids** - All concentrated acids can damage the skin and eyes and their burns are very painful. Nitric, chromic, and hydrofluoric acids are especially damaging. Rinse for 15 minutes in the nearest emergency eyewash or shower as appropriate and seek immediate medical treatment if you have been contaminated with any corrosive chemical, including acids. Hydrofluoric acid (HF) is especially dangerous and has specific emergency procedures and an antidote gel and eyewash solution that is required in all locations where HF is used or stored. See Section 2.6.3 for HF medical treatment information.

**Strong bases** - Common strong alkalis (bases) used in laboratories are metal hydroxides and ammonia. Burns from these materials are often less painful than acids. However, damage may be more severe than painful acid burns because the injured person, feeling little pain, may not take immediate action and allow the material to penetrate into the tissue. Ammonia is also a severe bronchial irritant and should always be used in a chemical fume hood. Rinse for 15 minutes in the nearest emergency eyewash or shower as appropriate and seek immediate medical treatment if you have been contaminated with any corrosive chemical, including bases.

**Dehydrating agents** - This group of chemicals includes concentrated sulfuric acid, sodium hydroxide, phosphorus pentoxide and calcium oxide. Because heat is evolved on mixing these substances with water, mixing should always be done by adding the agent to water, and not the reverse, to avoid violent reaction and spattering. Because of their affinity for water, these substances cause very severe burns on contact with skin. Affected areas should be washed promptly with large volumes of water at an approved emergency eyewash or emergency shower for 15 minutes to ensure all agent is removed before seeking immediate medical attention.

**Oxidizing agents** - In addition to their corrosive properties, similar to those described above, powerful oxidizing agents such as concentrated hydrogen peroxide (>30%), bromine, chlorine, perchloric acid and chromic acid present fire hazards on contact with organic compounds and other oxidizable substances. They also have serious corrosive effects and should not come into contact with the skin or eyes. All handling of powerful oxidizing agents should be handled only after thorough familiarization with recommended operating procedures for highly reactive compounds (see Section 3.2).

#### 3.4.2 Special Handling Procedures - See SOP in Appendix Q

When working with corrosive chemicals wear gloves, safety glasses or goggles, long sleeved lab coat and closed toe shoes. Handling of bulk quantities of these chemicals requires use of rubber aprons and the combined use of
face shields and goggles, as well as utility grade gloves. Refer to the PPE assessment tool for required personal protective equipment for your operation.

Corrosive chemicals should only be handled inside a chemical fume hood. Use plastic trays for containment when handled in bulk quantities (> 1 liter) and when dispensing.

An eyewash and safety shower should be close by within a 10 second unobstructed run from areas where corrosive chemicals are handled. Spill materials, including absorbents and neutralizing materials should be available in the laboratory.

Store corrosive chemicals in cabinets designed for corrosive chemicals, if possible. If these cabinets are not available, store them under fume hoods or on low shelves in impervious trays to separate them physically from other groups of chemicals. Do not store volatile corrosive chemicals such as hydrochloric acid inside a flammable cabinet, since the vapors will cause corrosion to these cabinets. Keep containers not in use in storage areas and off bench tops.

Use a chemical carrier whenever moving corrosive chemicals from one laboratory to another or from the stockroom.

3.5 REGULATED CHEMICALS & PARTICULARLY HAZARDOUS CHEMICALS – CARCINOGENS, REPRODUCTIVE TOXINS, AND ACUTELY TOXIC MATERIALS

3.5.1 General Information

This section establishes supplemental work procedures to control the handling of chemicals of high acute and chronic toxicity, such as carcinogens, reproductive toxins and highly toxic chemicals. Chemicals that possess the characteristic of high acute toxicity may be fatal or cause damage to target organs as a result of a single exposure or exposures of short duration. Chemicals that possess the characteristic of high chronic toxicity cause damage after repeated exposure or exposure over long periods of time, with health effects often not becoming evident until after a latency period of many years.

Chemical carcinogens listed and regulated by the Department of Labor, Occupational Safety and Health Administration (OSHA), and of human carcinogens listed by the International Agency for Research on Cancer (IARC) and the National Toxicology Program (NTP) are covered by this section.

The location and volume of all of these chemicals are identified in the Yale University EHS Integrator Chemical Management System. This inventory these chemicals is updated by each laboratory on a regular basis.

3.5.2 Special Handling Procedures – See SOPs in Appendices R and S

An SOP should be available and reviewed by the PI or designated senior lab personnel for work involving these materials. See Appendix R for SOPs that offer general guidance for working with carcinogens, reproductive toxins, and acutely toxic materials.

Avoid or minimize contact with these chemicals by any route of exposure. Protect yourself by wearing gloves, long pants, closed toe shoes and long sleeved laboratory coat. Protect your eyes with safety goggles or glasses. If the procedure involving use of these chemicals has a potential for splashing, wear an impermeable apron or coveralls, and a face shield in addition to goggles. Wear disposable garments if others may be placed at risk during the laundering process. Refer to the PPE assessment tool to determine the appropriate personal protective equipment for your operation.
All personal protective equipment should be removed before leaving the designated area. If necessary, decontaminate PPE and if disposable, placed in a plastic bag and secured before disposal. Skin surfaces - hands, forearms, face and neck - should be washed immediately.

Use these chemicals only in a chemical fume hood or other approved appropriate containment device, such as a glove box.

Analytical instruments or other laboratory equipment generating vapors and/or aerosols during their operation should be locally exhausted or vented in a chemical fume hood.

Particularly hazardous chemicals that are volatile should be stored in a vented storage area in an unbreakable, primary or secondary container or placed in a chemically resistant tray to contain spills. Nonvolatile hazardous chemicals should be stored securely in cabinets or in drawers. *Do not store these chemicals on open shelves or counters.* Access to all of these chemicals should be restricted. Cyanide salts and some chemical listed as a chemical warfare agent must be stored in a locked cabinet or locked storage area.

All hazardous chemicals should be transported between laboratories in durable outer containers or chemical carriers.

All procedures with these chemicals should be performed in designated areas. The designated area can be the entire laboratory, an area within a laboratory, or a storage or containment device such as a laboratory fume hood. Others working in the area should be informed of the particular hazards associated with these substances and the appropriate precautions that are necessary for preventing exposures. All designated areas should be posted with a sign which reads:

**WARNING**
**DESIGNATED AREA**
for select carcinogens, reproductive toxins and high acute toxicity chemicals
**AUTHORIZED PERSONNEL ONLY**

As an alternative, if the laboratory door sign has one of the following symbols, the entire laboratory is considered to be a designated area:

Work surfaces on which these substances will be handled should be covered with an easily decontaminated surface or protected from contamination with plastic trays or plastic backed paper. Call Environmental Health and Safety for substance-specific decontamination and disposal procedures. Materials that will be disposed of should be placed in plastic bags and secured.

Chemical wastes from procedures using these substances should be placed in containers, tagged, and placed in the designated satellite accumulation area until picked up by EHS. If possible, chemically decontaminate all toxic substances to nontoxic materials as part of the procedure. Call EHS for decontamination procedures.

Normal laboratory work should not be conducted in a designated area until it has been decontaminated or determined to be acceptable by the principal investigator, laboratory supervisor or your EHS Safety Advisor.

Lab personnel of childbearing age should be informed of any known reproductive toxins used in the laboratory. A researcher who is pregnant, or planning to become pregnant, and who is working with potential reproductive
toxins that might affect the fetus, should contact Environmental Health and Safety to evaluate their exposure. This researcher should also inform the Employee Health Physician and her personal physician of the particular substance being used as necessary. The Chemical Hygiene Officer can assess potential exposures and work with the principal investigator or laboratory supervisor, if necessary, to adjust work practices to minimize the potential risk.

Examples of highly toxic solids and liquids are listed in Appendix T. Purchases of these chemicals are flagged as restricted and will be routed to EHS for approval. An inventory of these chemicals is maintained in Yale’s chemical inventory system. A written SOP is required for all work involving these chemicals.

Examples of carcinogens and reproductive toxins are listed in Appendix U. Purchases of these chemicals are flagged as restricted and will be routed to EHS for approval. An SOP will be required for all work involving these chemicals.

3.6 DEPARTMENT OF HOMELAND SECURITY (DHS) REGULATED CHEMICALS

3.6.1 General Information

Congress and the Department of Homeland Security, in the Chemical Facility Anti-terrorism Standards Interim Final Rule (http://www.dhs.gov/xprevprot/laws/gc_1166796969417.shtm), have mandated that all workplaces, including universities, inventory and report on the presence and location of specific “chemicals of interest”. These chemicals are now identified separately as restricted items and purchase of these chemicals are flagged and routed to EHS for approval, and a container level inventory of these chemicals is maintained. Chemicals that are identified by DHS as “Chemicals of Interest” can be found listed in Appendix V.

3.6.2 Special Handling Procedures

Use these chemicals only in a chemical fume hood or other appropriate containment device, such as a glove box. If a chemical fume hood is used it should be evaluated to confirm that it is performing adequately. This can be confirmed by checking the face velocity monitor on the front of the hood, or using a handheld vaneometer for older fume hoods that do not have a face velocity monitor.

Volatile chemicals should be stored in a vented storage area in an unbreakable, primary or secondary container or placed in a chemically resistant tray to contain spills. Nonvolatile hazardous chemicals should be stored in cabinets or in drawers. Do not store these chemicals on open shelves or counters. Access to all of these chemicals should be restricted. Some of these chemicals must be stored in a locked cabinet or locked storage area. Those with these special storage requirements are identified in the Appendix.

All hazardous chemicals should be transported between laboratories in durable outer containers or chemical carriers.

Handling of any of these chemicals require approval from EHS and a written SOP in the laboratory that has been reviewed by the PI or designated Senior Researcher.

SECTION 4.0 CHEMICAL TOXICOLOGY

4.1 CHEMICAL TOXICOLOGY OVERVIEW
4.1.1 Definitions

**Toxicology** is the study of the nature and action of poisons.

**Toxicity** is the ability of a chemical substance or compound to produce injury once it reaches a susceptible site in, or on, the body.

A material's **hazard potential** is the probability that injury will occur after consideration of the conditions under which the substance is used.

4.1.2 Dose-Response Relationships

The potential toxicity (harmful action) inherent in a substance is exhibited only when that substance comes in contact with a living biological system. The potential toxic effect increases as the exposure increases. All chemicals will exhibit a toxic effect given a large enough dose. The toxic potency of a chemical is thus ultimately defined by the dose (the amount) of the chemical that will produce a specific response in a specific biological system.

4.1.3 Routes of Entry into the Body

There are three main routes by which hazardous chemicals enter the body:

- Absorption through the **respiratory tract** via inhalation.
- Absorption through the **skin** via dermal contact.
- Absorption through the **digestive tract** via ingestion. (Ingestion can occur through eating or smoking with contaminated hands or in contaminated work areas.)

Most exposure standards, such as the Threshold Limit Values (TLVs) and Permissible Exposure Limits (PELs), are based on the inhalation route of exposure. These limits are normally expressed in terms of either parts per million (ppm) or milligrams per cubic meter (mg/m³) concentration in air. If a significant route of exposure for a substance is through skin contact, the MSDS, PEL and/or TLV will have a "skin" notation. Examples of substances where skin absorption may be a significant factor include: pesticides, carbon disulfide, carbon tetrachloride, dioxane, mercury, thallium compounds, xylene and hydrogen cyanide.

4.1.4 Types of Effects

**Acute poisoning** is characterized by sudden and severe exposure and rapid absorption of the substance. Normally, a single large exposure is involved. Adverse health effects are often reversible. Examples: carbon monoxide or cyanide poisoning.

**Chronic poisoning** is characterized by prolonged or repeated exposures of a duration measured in days, months or years. Symptoms may not be immediately apparent. Health effects are often irreversible. Examples: lead or mercury poisoning.

A **Local** effect refers to an adverse health effect that takes place at the point or area of contact. The site may be skin, mucous membranes, the respiratory tract, gastrointestinal system, eyes, etc. Absorption does not necessarily occur. Examples: strong acids or alkalis.

**Systemic** effect refers to an adverse health effect that takes place at a location distant from the body's initial point of contact and presupposes absorption has taken place. Examples: arsenic affects the blood, nervous system, liver, kidneys and skin; benzene affects bone marrow.
Cumulative poisons are characterized by materials that tend to build up in the body as a result of numerous chronic exposures. The effects are not seen until a critical body burden is reached. Example: heavy metals.

Substances in combination: When two or more hazardous materials are present at the same time, the resulting effect can be greater than the effect predicted based on the additive effect of the individual substances. This is called a synergistic or potentiating effect. Example: exposure to alcohol and chlorinated solvents; or smoking and asbestos.

4.1.5 Other Factors Affecting Toxicity

- **Rate of entry** and route of exposure; that is, how fast is the toxic dose delivered and by what means.
- **Age** can affect the capacity to repair tissue damage.
- **Previous exposure** can lead to tolerance, increased sensitivity or make no difference.
- **State of health, physical condition and life style** can affect the toxic response.
- **Pre-existing disease** can result in increased sensitivity.
- **Environmental factors** such as temperature and pressure.
- Host factors including genetic predisposition and the sex of the exposed individual.

4.1.6 Physical Classifications

**Gas** applies to a substance which is in the gaseous state at room temperature and pressure.

A **Vapor** is the gaseous phase of a material which is ordinarily a solid or a liquid at room temperature and pressure.

When considering the toxicity of gases and vapors, the solubility of the substance is a key factor. Highly soluble materials, like ammonia, irritate the upper respiratory tract. On the other hand, relatively insoluble materials, like nitrogen dioxide, penetrate deep into the lung. Fat soluble materials, like pesticides, tend to have longer residence times in the body and be cumulative poisons.

An **aerosol** is composed of solid or liquid particles of microscopic size dispersed in a gaseous medium.

The toxic potential of an aerosol is only partially described by its airborne concentration. For a proper assessment of the toxic hazard, the size of the aerosol's particles must be determined. A particle's size will determine if a particle will be deposited within the respiratory system and the location of deposition. Particles above 10 micrometers tend to deposit in the nose and other areas of the upper respiratory tract. Below 10 micrometers particles enter and are deposited in the lung. Very small particles (<0.2 micrometers) are generally not deposited but exhaled.

4.1.7 Physiological Classifications

**Irritants** are materials that cause inflammation of mucous membranes with which they come in contact. Inflammation of tissue results from exposure to concentrations far below those needed to cause corrosion. Irritants can also cause changes in the mechanics of respiration and lung function. Long term exposure to irritants can result in increased mucous secretions and chronic bronchitis.

A **primary irritant** exerts no systemic toxic action either because the products formed on the tissue of the respiratory tract are non-toxic or because the irritant action is far in excess of any systemic toxic action. Example: dilute hydrogen chloride.
A secondary irritant’s effect on mucous membranes is overshadowed by a systemic effect resulting from absorption. Examples: Hydrogen sulfide, Aromatic hydrocarbons.

**Asphyxiants** have the ability to deprive tissue of oxygen.

**Simple asphyxiants** are inert gases that displace oxygen. Examples: Nitrogen, Helium, Carbon dioxide.

**Chemical asphyxiants** reduce the body’s ability to absorb, transport, or utilize inhaled oxygen. They are often active at very low concentrations (a few ppm). Examples: Carbon monoxide, Cyanides.

**Primary anesthetics** have a depressant effect upon the central nervous system, particularly the brain. Examples: Halogenated hydrocarbons, Alcohols.

**Hepatotoxic agents** cause damage to the liver. Examples: Carbon tetrachloride, Tetrachloroethane, Nitrosamines.

**Nephrotoxic agents** damage the kidneys. Examples: Halogenated hydrocarbons, Uranium compounds.

**Neurotoxic agents** damage the nervous system. The nervous system is especially sensitive to organometallic compounds and certain sulfide compounds. Examples include:
- Trialkyl tin compounds
- Methyl mercury
- Organic phosphorus insecticides
- Manganese

Some toxic agents act on the **blood** or **hematopoietic system**. The blood cells can be affected directly or the bone marrow (which produces the blood cells) can be damaged. Examples: Nitrites, Aniline, Toluidine, Nitrobenzene, Benzene.

There are toxic agents that produce damage of the **pulmonary tissue** (lungs) but not by immediate irritant action. Fibrotic changes can be caused by free silica and asbestos. Other dusts can cause a restrictive disease called **pneumoconiosis**. Examples: Coal dust, Cotton dust, Wood dust.

A **carcinogen** means a substance or a mixture of substances which induce cancer or increase its incidence. Substances and mixtures which have induced benign and malignant tumors in well-performed experimental studies on animals are considered also to be presumed or suspected human carcinogens unless there is strong evidence that the mechanism of tumor formation is not relevant for humans.

A chemical is considered a carcinogen or potential carcinogen if it is listed in any of the following publications:
- National Toxicology Program, *Annual Report on Carcinogens* (latest edition) – listed under the category of “known to be carcinogens”
- International Agency for Research on Cancer, *Monographs* (latest edition) – listed as either Group 1, Group 2A or Group 2B
- Regulated by OSHA as a carcinogen under 29 CFR 1910 Subpart Z, *Toxic and Hazardous Substances*

Known human carcinogens include:

- Asbestos
- Formaldehyde
- Vinyl chloride
- Methyl chloromethyl ether
- Benzene
- Bis-chloromethyl ether

A **mutagen** causes heritable changes (mutations) in the genetic material (DNA) of exposed cells. If germ cells are involved, the effect may be inherited and become part of the genetic pool passed onto future generations. Ethidium bromide is an example of a mutagen.
A **teratogen** (embryotoxic or fetotoxic agent) is an agent which interferes with normal embryonic development without causing a lethal effect to the fetus or damage to the mother. Effects are not inherited. Examples: Lead, Thalidomide.

A **sensitizer** is a chemical which can cause an allergic reaction in normal tissue after repeated exposure to the chemical. The reaction may be as mild as a rash (allergic dermatitis) or as serious as anaphylactic shock. Examples: Epoxy compounds, Toluene diisocyanate, Nickel compounds, Chromium compounds, Poison ivy, Formaldehyde, d-Limonene.

### 4.2 SOME TARGET ORGAN EFFECTS

The following is a categorization of target organ effects which may occur from chemical exposure. Signs and symptoms of these effects and examples of chemicals which have been found to cause such effects are listed.

<table>
<thead>
<tr>
<th>Toxins</th>
<th>Target organ effect</th>
<th>Signs and symptoms</th>
<th>Example chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatotoxins</td>
<td>Cause liver damage</td>
<td>Jaundice; liver enlargement</td>
<td>Nitrosamines, chloroform, toluene, perchloro-ethylene, cresol, dimethylsulfate</td>
</tr>
<tr>
<td>Nephrotoxins</td>
<td>Cause kidney damage</td>
<td>Edema; proteinuria</td>
<td>Halogenated hydrocarbons, uranium, chloroform, mercury, dimethylsulfate</td>
</tr>
<tr>
<td>Neurotoxins</td>
<td>Affect the nervous system</td>
<td>Narcosis; behavior changes; decreased muscle coordination</td>
<td>Mercury, carbon disulfide, benzene, carbon tetrachloride, lead, mercury, nitrobenzene</td>
</tr>
<tr>
<td>Hematopoietic toxins</td>
<td>Decrease blood function</td>
<td>Cyanosis; loss of consciousness</td>
<td>Carbon monoxide, cyanides, nitro-benzene, aniline, arsenic, benzene, toluene</td>
</tr>
<tr>
<td>Pulmonary toxins</td>
<td>Irritate or damage the lungs</td>
<td>Cough; tightness in chest, shortness of breath</td>
<td>Silica, asbestos, ozone, hydrogen sulfide, chromium, nickel, alcohols</td>
</tr>
<tr>
<td>Reproductive toxins</td>
<td>Affect the reproductive system</td>
<td>Birth defects; infertility</td>
<td>Lead, 2-ethoxyethanol, dibromodichloropropane,</td>
</tr>
<tr>
<td>Skin hazards</td>
<td>Affect the dermal layer of the body</td>
<td>Defatting of skin; rashes; irritation</td>
<td>Ketones, chlorinated compounds, alcohols, nickel, phenol, trichloroethylene</td>
</tr>
<tr>
<td>Eye hazards</td>
<td>Affect the eye or vision</td>
<td>Conjunctivitis, corneal damage</td>
<td>Organic solvents, acids, cresol, quinone, hydroquinone, benzol, chloride, butyl alcohol, methanol, bases</td>
</tr>
</tbody>
</table>

### 4.3 OCCUPATIONAL HEALTH STANDARDS

**TLV:** The **threshold limit value** is a recommended occupational exposure guideline published by the American Conference of Governmental Industrial Hygienists. TLVs are expressed as parts of vapor or gas per million parts of air by volume (ppm) or as approximate milligrams of particulate per cubic meter or air (mg/M$^3$). The TLV is the average concentration of a chemical that most people can be exposed to for a working lifetime with no ill effects. The TLV is an advisory guideline. If applicable, a **ceiling concentration** (C) that should not be exceeded or a **skin** absorption notation (S) will be indicated with the TLV.

**PEL:** The **permissible exposure limit** is a legal standard issued by OSHA. Unless specified, the PEL is a time weighted average (TWA).

**TWA:** Most exposure standards are based on **time weighted averages**. The TWA is the average exposure over an eight (8) hour work day. Some substances have short term exposure limits (STELs). These levels are time
weighted over a 15 minute period, and exposures should not exceed the STEL in any 15 minute period over the course of an 8 hour work day. Some substances have Ceiling (C) limits. Ceiling limits are concentrations that should never be exceeded.

The SDS will list the occupational health standard(s) for the hazardous chemical or each component of a mixture.

The Office of Environmental Health and Safety has a complete listing of published TLVs and PELs and other information concerning the subject of chemical toxicology. If you would like to conduct a more thorough review of a particular compound, contact the Office of Environmental Health and Safety. The list of available references in the Office of Environmental Health and Safety library is indicated in Appendix C.
SECTION 5.0 GLOSSARY OF TERMS

ACGIH - The American Conference of Governmental Industrial Hygienists - a voluntary membership organization of professional industrial hygiene personnel. The ACGIH develops and publishes recommended occupational exposure limits each year called Threshold Limit Values (TLV's) for hundreds of chemicals, physical agents, and biological exposure indices.

ACUTE - Short duration, rapidly changing conditions.

ACUTE EXPOSURE - An intense exposure over a relatively short period of time.

ANSI - The American National Standards Institute - a voluntary membership organization (run with private funding) that develops consensus standards nationally for a wide variety of devices and procedures.

ASPHYXIANT - A chemical (gas or vapor) that can cause death or unconsciousness by suffocation. Simple asphyxiants, such as nitrogen, either remove or displace oxygen in the air. They become especially dangerous in confined or enclosed spaces. Chemical asphyxiants, such as carbon monoxide and hydrogen sulfide, interfere with the body's ability to absorb or transport oxygen to the tissues.

BOILING POINT - The temperature at which the vapor pressure of a liquid equals atmospheric pressure or at which the liquid changes to a vapor. The boiling point is usually expressed in degrees Fahrenheit. If a flammable material has a low boiling point, it indicates a special fire hazard.

"C" OR CEILING - A description usually seen in connection with ACGIH exposure limits. It refers to the concentration that should not be exceeded, even for an instant. It may be written as TLV-C or Threshold Limit Value-Ceiling. (See also THRESHOLD LIMIT VALUE).

CARCINOGEN - A substance or physical agent that may cause cancer in animals or humans.

CAS NUMBER - Identifies a particular chemical by the Chemical Abstracts Service, a service of the American Chemical Society that indexes and compiles abstracts of worldwide chemical literature called Chemical Abstracts.

cc - Cubic centimeter, a volumetric measurement which is also equal to one milliliter (ml).

°C - Degrees, Celsius; a temperature scale.

CHEMICAL - As broadly applied to the chemical industry, an element or a compound produced by chemical reactions on a large scale for either direct industrial and consumer use or for reaction with other chemicals.

CHEMICAL REACTION - A change in the arrangement of atoms or molecules to yield substances of different composition and properties. (see REACTIVITY)

CHRONIC - Persistent, prolonged or repeated conditions.

CHRONIC EXPOSURE - A prolonged exposure occurring over a period of days, weeks, or years.

COMBUSTIBLE - Substances such as wood, paper, etc., are termed "Ordinary Combustibles" and can readily ignite in elevated temperatures or in a fire. According to the NFPA, combustible liquids are those having a flash point between 100-200°F. They do not ignite as easily as flammable liquids at room temperature.

CONCENTRATION - The relative amount of a material in combination with another material - for example, 5 parts of (acetone) per million (parts of air) = 5 ppm acetone.
CORROSIVE - A substance that, according to the DOT, is highly corrosive to steel. In addition, OSHA states that corrosive substances will cause visible destruction or permanent changes in human skin tissue at the site of contact.

CUTANEOUS - Pertaining to or affecting the skin.

DECOMPOSITION - The breakdown of a chemical or substance into different parts or simpler compounds. Decomposition can occur due to heat, chemical reaction, decay, etc.

DERMAL - Pertaining to or affecting the skin.

DERMATITIS - An inflammation of the skin.

DILUTION VENTILATION - See GENERAL VENTILATION.

DOT - The United States Department of Transportation - the federal agency that regulates the labeling and transportation of hazardous materials.

DYSPNEA - Shortness of breath; difficult or labored breathing.

EPA - The Environmental Protection Agency - the governmental agency responsible for administration of laws to control and/or reduce pollution of air, water, and land systems.

EPA NUMBER - The number assigned to chemicals regulated by the Environmental Protection Agency (EPA).

EPIDEMIOLOGY - The study of disease in human populations.

ERYTHEMA - A reddening of the skin.

EVAPORATION RATE - The rate at which a material is converted to vapor (evaporates) at a given temperature and pressure. Health and fire hazard evaluations of materials involve consideration of evaporation rates as one aspect of the evaluation.

°F - Degrees, Fahrenheit; a temperature scale.

FLASH POINT - The minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid.

FLAMMABLE LIQUID - According to the NFPA, a flammable liquid is one that has a flash point below 100°F. (See FLASH POINT). DOT defines flammable liquids as those that have a flash point below 140°F. OSHA defines flammable liquids as those having a flash point of below 200°F.

GENERAL VENTILATION - Also known as general exhaust ventilation, this is a system of ventilation consisting of either natural or mechanically induced fresh air movements to mix with and dilute contaminants in the workroom air. This is not the recommended type of ventilation to control hazardous contaminants. (See LOCAL EXHAUST VENTILATION).

GRAM (g) - A metric unit of weight. One ounce equals 28.4 grams.
GRAMS PER KILOGRAM (g/Kg) - This indicates the dose of a substance given to test animals in toxicity studies. For example, a dose may be 2 grams (of substance) per kilogram of body weight (of the experimental animal).

HAZARDOUS MATERIAL - Any substance or compound that has the capability of producing adverse effects on the health and safety of humans.

IGNITABLE - A solid, liquid or compressed gas that has a flash point of less than 140°F. Ignitable material are regulated by the EPA as a hazardous waste.

INCOMPATIBLE - The term applied to two substances to indicate that one material cannot be mixed with the other without the possibility of a dangerous reaction.

INGESTION - Taking a substance into the body through the mouth, such as food, drink, medicine, or unknowingly as in contaminated hands or cigarettes, etc.

INHALATION - Breathing in of an airborne substance that may be in the form of gases, fumes, mists, vapors, dusts, or aerosols.

INHIBITOR - A substance that is added to another to prevent or slow down an unwanted reaction or change.

IRRITANT - A substance that produces an irritating effect when it contacts skin, eyes, nose, or respiratory system.

KILOGRAM (Kg) - A unit of weight in the metric system equal to 2.2 pounds.

LEL - See LOWER EXPLOSIVE LIMIT.

LETHAL CONCENTRATION₅₀ (LC₅₀) - The concentration of an air contaminant that will kill 50 percent of the test animals in a group during a single exposure. This test is used to determine toxicity of a substance.

LETHAL DOSE₅₀ (LD₅₀) - The dose of a substance or chemical that will kill 50 percent of the test animals in a group within the first 30 days following exposure. This test is used to determine toxicity of a substance.

LITER (L) - A measure of capacity. One quart equals 0.9 liters.

LOCAL EXHAUST VENTILATION - A ventilation system that captures and removes contaminants at the point where they are being produced before they escape into the workroom air. The system consists of hoods, ducts, a fan and possibly an air cleaning device. Advantages of local exhaust ventilation over general ventilation include: removes the contaminant rather than dilutes it; requires less air flow and thus is more economical over the long term; and the system can be used to conserve or reclaim valuable materials. However, the system must be properly designed with the correctly shaped and placed hoods, and correctly sized fans and duct work.

LOWER EXPLOSIVE LIMIT (LEL) - (Also known as Lower Flammable Limit). The lowest concentration of a substance that will produce a fire or flash when an ignition source (flame, spark, etc.) is present. It is expressed in percent of vapor or gas in the air by volume. Below the LEL or LFL, the air/contaminant mixture is theoretically too "lean" to burn. (See also UEL).

MELTING POINT - The temperature at which a solid changes to a liquid. A melting range may be given for mixtures.

MILLIGRAM (mg) - A unit of weight in the metric system. One thousand milligrams equal one gram.
MILLIGRAMS PER CUBIC METER (mg/m³) - Units used to measure air concentrations of dusts, gases, mists, and fumes.

MILLIGRAMS PER KILOGRAM (mg/kg) - This indicates the dose of a substance given to test animals in toxicity studies. For example, a dose may be 2 milligrams (of substance) per kilogram of body weight (of the experimental animal).

MILLILITER (ml) - A metric unit used to measure capacity. One milliliter equals one cubic centimeter. One thousand milliliters equal one liter.

MSHA - The Mine Safety and Health Administration; a federal agency that regulates the mining industry in the safety and health area.

MUTAGEN - Anything that can cause an inherited change (or mutation) in the genetic material of a living cell.

NARCOSIS - Stupor or unconsciousness caused by exposure to a chemical.

NFPA - The National Fire Protection Association is a voluntary membership organization whose aims are to promote and improve fire protection and prevention. NFPA has published 16 volumes of codes known as the National Fire Codes. Within these codes is Standard No. 704, Identification of the Fire Hazards of Materials. This is a system that rates the hazard of a material during a fire. These hazards are divided into health, flammability, and reactivity hazards and appear in a well-known diamond system using from zero through four to indicate severity of the hazard. Zero indicates no special hazard and four indicates severe hazard.

NIOSH - The National Institute of Occupational Safety and Health is a federal agency that among its various responsibilities trains occupational health and safety professionals, conducts research on health and safety concerns, and tests and certifies respirators for workplace use.

ODOR THRESHOLD - The minimum concentration of a substance at which a majority of test subjects can detect and identify the substance's characteristic odor.

OSHA - The Occupational Safety and Health Administration - a federal agency under the Department of Labor that publishes and enforces safety and health regulations for most businesses and industries in the United States.

OXIDATION - The process of combining oxygen with some other substance to a chemical change in which an atom loses electrons.

OXIDIZER - A substance that gives up oxygen easily to stimulate combustion of organic material.

OXYGEN DEFICIENCY - An atmosphere having less than the normal percentage of oxygen found in normal air. Normal air contains 20.9% oxygen at sea level.

PERMISSIBLE EXPOSURE LIMIT (PEL) - An exposure limit that is published and enforced by OSHA as a legal standard. PEL may either be a time-weighted-average (TWA) exposure limit (8 hour), a 15-minute short term exposure limit (STEL), or a ceiling (C). PEL's are found in Tables Z-1, Z-2, or Z-3 of OSHA regulations 1910.1000, and in the chemical-specific standards under Subpart Z.

PERSONAL PROTECTIVE EQUIPMENT - Any devices or clothing worn by the worker to protect against hazards in the environment. Examples are respirators, gloves, safety glasses.
POLYMERIZATION - A chemical reaction in which two or more small molecules combine to form larger molecules that contain repeating structural units of the original molecules. A hazardous polymerization is the above reaction with an uncontrolled release of energy.

ppm - Parts (of vapor or gas) per million (parts of air) by volume.

REACTIVITY - A substance's susceptibility to undergoing a chemical reaction or change that may result in dangerous side effects, such as explosions, burning, and corrosive or toxic emissions. The conditions that cause the reaction, such as heat, other chemicals, and shaking or dropping, will usually be specified as "Conditions to Avoid" when a chemical's reactivity is discussed on a SDS.

RESPIRATOR - A device which is designed to protect the wearer from inhaling harmful contaminants.

RESPIRATORY HAZARD - A particular concentration of an airborne contaminant that, when it enters the body by way of the respiratory system or by being breathed into the lungs, results in some bodily function impairment.

SENSITIZER - A substance that may cause no reaction in a person during initial exposures, but afterwards, further exposures will cause an allergic response to the substance.

SHORT TERM EXPOSURE LIMIT (STEL) - Represented as STEL or TLV-STEL, this is the maximum concentration to which workers can be exposed for a short period of time (15 minutes) for only four times throughout the day with at least one hour between exposures. Also the daily TLV-TWA must not be exceeded.

"SKIN" - This designation sometimes appears alongside a TLV or PEL. It refers to the possibility of absorption of the particular chemical through the skin and eyes. Thus, protection of large surface areas of skin should be considered to prevent skin absorption so that the TLV is not invalidated.

SUBSTANCE - Any chemical entity.

SYNONYM - Another name by which the same chemical may be known.

SYSTEMIC - Spread throughout the body; affecting many or all body systems or organs; not localized in one spot or area.

TERATOGEN - An agent or substance that may cause physical defects in the developing embryo or fetus when a pregnant female is exposed to that substance.

THRESHOLD LIMIT VALUE (TLV) - Airborne concentrations of substances devised by the ACGIH that represent conditions under which it is believed that nearly all workers may be exposed day after day with no adverse effect. TLV's are advisory exposure guidelines that are based on evidence from industrial experience, animal studies, or human studies when they exist. There are three different types of TLV's: Time Weighted Average (TLV-TWA), Short Term Exposure Limit (TLV-STEL) and Ceiling (TLV-C). (See also PEL.)

TIME WEIGHTED AVERAGE - The average time, over a given work period (e.g. 8-hour work day), of a person's exposure to a chemical or an agent. The average is determined by sampling for the contaminant throughout the time period. Represented as TLV-TWA.

TOXICITY - The potential for a substance to exert a harmful effect on humans or animals and a description of the effect and the conditions or concentrations under which the effect takes place.
TRADE NAME - The commercial name or trademark by which a chemical is known. One chemical may have a variety of trade names depending on the manufacturers or distributors involved.

UNSTABLE LIQUID - A liquid that, in its pure state or as commercially produced, will react vigorously in some hazardous way under shock conditions (i.e., dropping), certain temperatures, or pressures.

UPPER EXPLOSIVE LIMIT (UEL) - Also known as Upper Flammable Limit. Is the highest concentration (expressed in percent of vapor or gas in the air by volume) of a substance that will burn or explode when an ignition source is present. Theoretically above this limit the mixture is said to be too "rich" to support combustion. The difference between the LEL and the UEL constitutes the flammable range or explosive range of a substance. That is, if the LEL is 1ppm and the UEL is 5ppm, then the explosive range of the chemical is 1ppm to 5ppm. (see also LEL).

VAPOR - The gaseous form of substances which are normally in the liquid or solid state (at normal room temperature and pressure). Vapors evaporate into the air from liquids such as solvents. Solvents with low boiling points will evaporate.
APPENDIX A  SUMMARY OF OSHA'S LABORATORY STANDARD

"Occupational Exposures to Hazardous Chemicals in Laboratories"
29 CFR 1910.1450

The Laboratory Health Standard requires laboratories to develop procedures that help to ensure that occupational exposure to hazardous chemicals in the laboratory environment is reduced or minimized.

OSHA summarizes the intent of the standard in the preamble:

"The new standard differs from many OSHA health standards in that it does not establish new exposure limits, but sets other performance provisions designed to protect laboratory workers from potential hazards in their work environment. By permitting a greater degree of flexibility to laboratories in developing and implementing employee safety and health programs, OSHA expects benefits to result from increased worker awareness of potential risks, improved work practices, appropriate use of existing personal protective equipment and greater use of engineering controls. Given the flexibility to design and implement innovative measures to reduce employee exposure to hazardous substances, employers also will reap rewards in terms of lower insurance premiums, lower property damage costs, lower turnover costs, less absenteeism and, in general, increased productivity. Finally, the potential decrease in acute and chronic health problems will result in overall benefits to society through the associated reduction in medical and productivity costs."

The Laboratory Health Standard is primarily a performance oriented standard, allowing individual laboratories to tailor their approaches to meeting the requirements of the standard to their individual circumstances.

A copy of this standard is readily available on the web at www.osha.gov. Your Safety Advisor from the Office of Environmental Health and Safety can also get a copy for you upon request.
Eating, drinking and smoking are prohibited in laboratories where radioisotopes, biological agents or hazardous chemicals are used, handled, or stored.

**This prohibition applies to an entire laboratory, note merely to areas within the laboratory where hazardous materials are used. This prohibition includes study carrels and desks that are not physically separated from the work area by floor-to-ceiling walls with doors that close, even if the space is not used for work with hazardous materials.**

This prohibition does not apply to space associated with laboratories (such as an interior office) that is physically separated from the laboratory area by floor-to-ceiling walls with doors which will close, and in which hazardous materials are never used or stored.*

In areas where eating and drinking are prohibited, food and beverages (and empty food and beverage containers) may not be stored, left or discarded. Government regulators and University EHS personnel may regard discarded food or beverage containers in a laboratory as evidence of eating or drinking in the laboratory.

Food or drink may be moved through a laboratory only if the food or beverage is wrapped or in a covered container.

Note* In Biosafety 3 laboratories, the prohibition applies to all areas, including interior offices and similar space even if it is separated by such barriers.
APPENDIX C  LABORATORY SAFETY REFERENCES

Located in the Office of Environmental Health and Safety Library

American Conference of Governmental Industrial Hygienists. *Guidelines for the Selection of Chemical Protective Clothing.*

American Conference of Governmental Industrial Hygienists. *ACGIH Threshold Limit Values for Chemical Substances and Physical Agents, and Biological Exposure Indices.* Updated Annually.


29CFR1910 Code of Federal Regulations, United States Department of Labor, OSHA.
APPENDIX D    RESEARCH PROTOCOL CHEMICAL SAFETY REVIEW

Date of Request: _______________________
Name: _______________________________________________________________
Email address: _________________________________________________________
Department: ___________________________________________________________
Location and phone: _________________________________________________
Principal Investigator: _________________________________________________

SUBSTANCE TO BE USED

Name: ______________________________ CAS No. _____________________
Identify all hazards (ex: flammable, toxic, carcinogen, reproductive, reactive, shock sensitive, etc):
___________________________________________________________

____________________________________________________
Identify routes of exposure (inhalation, dermal, etc): ______________________________
Location of Use (bldg, room, location within room)______________________________
Quantity Procured: _________________
Quantity/Concentration of Use: ______________________________________________
Storage Location/Conditions: ________________________________________________
Anticipated Start/End Dates: _______________________________
Frequency of Use: _________________________________________________________

PERSONNEL PROPOSED FOR THIS PROJECT
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

EXPERIMENTAL PROCEDURES
Briefly describe the research and procedures that will involve the use of this substance
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

Yale University Chemical Hygiene Plan  Revised Jan 2015
RATIONALE FOR USE
Justify why safer chemical/ procedure not used as substitute:
______________________________________________________________________________
______________________________________________________________________________

ENGINEERING CONTROLS
Describe engineering controls that will be employed to protect the individuals participating in this research
(ventilation, blast shield, equipment, etc):
______________________________________________________________________________
______________________________________________________________________________

PERSONAL PROTECTIVE EQUIPMENT
______________________________________________________________________________
______________________________________________________________________________

DECONTAMINATION AND DISPOSAL
Decontamination procedures to be used (surfaces, materials, instruments, equipment, etc.):
______________________________________________________________________________
______________________________________________________________________________
Disposal procedures (wastes, contaminated items, and unused stock):
______________________________________________________________________________

EMERGENCY PROCEDURES
In the event of personnel exposure, Be specific to your location and situation (phone, eyewash/shower, exits,
alarms, etc):
______________________________________________________________________________
______________________________________________________________________________
Equipment to be used in the event of environmental decontamination (spill control equipment/procedures) Be
specific to your location and situation:
______________________________________________________________________________

Completed form should be submitted to:
Yale University
Environmental Health and Safety
135 College Street, 1st floor
New Haven, CT 06510
Fax: 785-7588
APPENDIX E  PRELIMINARY HEALTH AND SAFETY INFORMATION SHEET

(Must be completed for chemical substances produced for another user outside the University)

CAUTION: The chemical, physical and toxicological properties of this chemical have not been fully investigated and its handling or use may be hazardous. Exercise due care.

Principal Investigator ________________________________
Campus address ______________________________________
Telephone __________________________________________
Date: ________________________________________________

CHEMICAL NAME_________________
SYNONYMS ______________________

CHEMICAL STRUCTURE

EMPIRICAL STRUCTURE __________
MOLECULAR WEIGHT _________

HEALTH REMARKS (identify known adverse affects)

FIRST AID PROCEDURES
Eye contamination (check appropriate items)
1. None necessary
2. Flush with water
3. Call physician
4. Other

Skin contamination (check appropriate items)
1. None necessary
2. Flush with water
3. Call physician

PHYSICAL PROPERTIES
Description ____________________________
_____________________________________
_____________________________________
Odor ________________________________
Boiling point ___________ °C
Melting point ___________ °C
Specific gravity ___________ g/ml
Solubility __________________________
Flash point ___________ °F
Flammable limits _________________

FIRE FIGHTING PROCEDURES (check appropriate items)
1. Water
2. Carbon dioxide
3. Foam
4. Dry chemicals
5. Special precautions

SPILL PROCEDURES
1. Eliminate ignition sources
2. Contain spill, dike
3. Wear respirator
4. Absorbent
5. Sweep
6. Flush residual with water

PROTECTIVE EQUIPMENT
None necessary
Goggles
Face shield
Gloves
Boots
Coveralls
Apron
Respirator
Chemical fume hood

WASTE DISPOSAL
Dispose of contaminated product and materials used in cleaning up spills or leaks in a manner approved for this material. Consult appropriate federal, state and local regulatory agencies to ascertain proper disposal procedures.
ATTENTION

Emergency Information - Unattended Operations

Contact Name:________________________________________________________

Contact Phone Number:________________________________________________

Date:_______________________________________________________________

Start time:_________ End time:__________

Chemical Identity and Quantities:
________________________________________________________________

Compressed Gases:
________________________________________________________________

Hazards:(circle all that apply) In Case of Emergency Shut off:
Corrosive Electricity
Toxic Vacuum
Reactive Gas Source
Flammable Water Source
Pressurized Hot Plate/Ignition Sources
Water Reactive
Electrical

Instructions: This form should be filled in complete and attached to the laboratory hood whenever a process is left unattended. Assume the worst-case scenario when determining which hazards apply.
APPENDIX G CHEMICAL HAZARD RISK ASSESSMENT FORM

Completing this document will help you to identify the risks associated with your research

Title of Experiment or Procedure:

Initial & Additional Review Date(s):

Brief Description of Experiment or Procedure (include reaction conditions (i.e. temperature, pressure) if applicable):

Known risks associated with the procedure (briefly describe hazard, probability (high medium low), consequence of occurrence)

Substances to be used (List ALL substances, including solvents, expected products and by-products):

<table>
<thead>
<tr>
<th>Substances Used</th>
<th>Approx. quantity</th>
<th>Physical form i.e. powder, vapour, volatile liquid, gas, etc</th>
<th>Hazards i.e. flammable, corrosive, irritant, readily absorbed through skin, etc.</th>
<th>Exposure route(s) e.g. skin, eyes</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

Risk implications:

Is there any substance used or formed that might give rise to a fire or explosion (e.g. flammable gases/liquids)?
If yes, how can you ensure that no explosion occurs?  Y/N

Is it reasonably foreseeable that the lower explosive limit will be reached in the event of a leak or spillage?
If yes, a more detailed risk assessment is required – contact ehs.  Y/N

Is there likelihood of copious amounts of gas being released or thermal runaway?
If experiment will be run continuously unattended, describe fail safe mechanisms/redundant systems used.  Y/N

Are any carcinogens, acutely toxic substances or chemicals requiring prior approval by EHS used?  Y/N

Can any of the substances be substituted by a less hazardous substance?  Y/N

What could happen if there was a catastrophic failure of the apparatus?

In the event of an accident, who might be exposed?
Control measures to be used:

### Containment
- Chemical fume hood
- Glove box
- Other local exhaust ventilation
- Blast guard/shield
- Other (specify)

### Personal Protective Equipment
- Lab coat (type):
- Chemical apron
- Gloves (type):
- Eye protection (type):
- Respiratory protective equipment *
  (type):
- Other (specify):

*Note: Contact EHS before wearing a respirator

**Are any additional controls required?** (Consider nearby sources of ignition, formation of explosive atmospheres/mixtures or residues, asphyxiation in confined spaces).

### Equipment to be used:

<table>
<thead>
<tr>
<th>Major Laboratory Equipment Used</th>
<th>Potential Hazards (i.e. electric shock, temperature extremes, pressure, chemical exposure)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Equipment controls required?

### Disposal measures to be used during and after the procedures:

**Emergency procedures** (emphasise any special hazards):
- Shut down Procedures
- Action in the event of Fire (type of extinguisher):
- Action in the event of spillage or uncontrolled release:
- Emergency treatment for personnel in the event of contamination, exposure to vapors or other adverse effects:

**Name of assessor:**

**Signature:**

**Date:**
**APPENDIX H SELECTION AND USE OF PERSONAL PROTECTIVE EQUIPMENT**

**Laboratory PPE Hazard Assessment Tool (This tool is available online at www.yale.edu/ehs)**

Check all Activities/Jobs/tasks that apply to your laboratory, and note any changes to personal protective equipment in the table and document their rationale at the end of this tool.

**Personal Protective Equipment to be worn at all times:**

<table>
<thead>
<tr>
<th>Applies</th>
<th>Activities/Jobs/Tasks</th>
<th>Potential Exposures Addressed by PPE</th>
<th>Personal Protective Equipment Requirements</th>
</tr>
</thead>
</table>
| ☑️      | Working in a laboratory where hazardous materials are used (exception: safety glasses are not required when sitting at a desk in the lab that is separated from the bench and there is minimal possibility of contamination) | • Contamination (feet, leg, clothing, eyes, hands)                         | • Closed-toe, solid top shoes  
• Clothing that covers the legs  
• Safety glasses or prescription glasses  
• Gloves if touching potentially contaminated equipment |

**Additional Personal Protective Equipment Requirements:**

<table>
<thead>
<tr>
<th>Applies</th>
<th>Activities/Jobs/Tasks</th>
<th>Potential Exposures Addressed by PPE</th>
<th>Personal Protective Equipment Requirements</th>
</tr>
</thead>
</table>
|         | Directly handling hazardous materials                                                                             | • Chemical, biological or radioactive material contamination (hands, eyes)  
• Contamination of personal clothing or skin (body) | • Safety glasses  
• Gloves—exam style—nitrile preferred (highly permeable, highly toxic materials may require different gloves— contact EHS)  
• Lab coat |
|         | Working with larger volumes (>1L) of corrosive or toxic liquids                                                 | • Splashing (eyes, face)  
• Contamination/burns to unprotected skin (hands, wrists, body)          | • Chemical goggles  
• Face shield if under pressure or outside fume hood  
• Gloves—utility grade nitrile or neoprene over nitrile exam style  
• Lab coat |
<table>
<thead>
<tr>
<th>Applies</th>
<th>Activities/Jobs/ Tasks</th>
<th>Potential Exposures Addressed by PPE</th>
<th>Personal Protective Equipment Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working directly with pyrophoric and water reactive chemicals</td>
<td>Burns (clothing, eyes, face, hands, body)</td>
<td>Wear non-synthetic clothing Work only inside a chemical fume hood or glove box Safety glasses or chemical goggles Face shield if splashing can occur Nitrile gloves Flame resistant gloves (larger volumes) Flame resistant lab coat Portable blast shield as necessary</td>
<td></td>
</tr>
<tr>
<td>Working with cryogenic materials</td>
<td>Cold burns (eyes, face, hands, body)</td>
<td>Safety glasses Face shield (larger volumes) Thermal insulated gloves Lab coat, apron or equivalent (larger volumes)</td>
<td></td>
</tr>
<tr>
<td>Working with hot objects or equipment</td>
<td>Burns (eyes, face, hands, body)</td>
<td>Safety glasses Face shield as necessary Heat resistant gloves Lab coat, apron or equivalent</td>
<td></td>
</tr>
<tr>
<td>Working with apparatus under high pressure</td>
<td>Cuts from glass/ material fragments (face, hands, body) Chemical contamination (eyes, face, hands, body)</td>
<td>Safety glasses or goggles Face shield Utility gloves Rubber apron as necessary Portable blast shield as necessary</td>
<td></td>
</tr>
<tr>
<td>Working with highly reactive or explosive chemicals</td>
<td>Cuts from glass/ material fragments (face, hands, body) Chemical contamination (eyes, face, hands, body) Fire</td>
<td>Work only inside a chemical fume hood Goggles Face shield Utility grade gloves—neoprene, butyl, nitrile, nomex, cut resistant, as appropriate Flame resistant lab coat when fire hazard exists Rubber apron Portable blast shield as necessary</td>
<td></td>
</tr>
<tr>
<td>Applies</td>
<td>Activities/Jobs/Tasks</td>
<td>Potential Exposures Addressed by PPE</td>
<td>Personal Protective Equipment Requirements</td>
</tr>
<tr>
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</tr>
<tr>
<td>Minor chemical spill cleanup (if &lt;1 liter of low hazard chemical, and respiratory protection is not required)</td>
<td>Chemical contamination (shoes, eyes, hands, clothing)</td>
<td>Shoe covers as necessary</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety glasses or goggles</td>
<td>Double nitrile gloves or utility grade gloves over nitrile exam gloves</td>
</tr>
<tr>
<td>UV light sources</td>
<td>Burns (eyes, face, neck, hands, wrist)</td>
<td>Full face shield (polycarbonate) over safety glasses</td>
<td>Nitrile gloves (wrists fully covered)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lab coat</td>
<td></td>
</tr>
<tr>
<td>Handling animals in a laboratory</td>
<td>Animal blood and other potentially infectious materials (eyes, hands)</td>
<td>Safety glasses</td>
<td>Gloves</td>
</tr>
<tr>
<td></td>
<td>Bites, scratches (hands, forearms, body)</td>
<td>Gown or lab coat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Allergens (respiratory or transfer to mucous membranes of the eyes, nose or mouth)</td>
<td>Refer to YARC for additional PPE requirements, which may differ depending on species, engineering controls, and hazardous agents used</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anesthetic agents (respiratory)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working with radioactive materials</td>
<td>Contamination of personal clothing (body)</td>
<td>Safety glasses</td>
<td>Gloves (double gloves recommended)</td>
</tr>
<tr>
<td></td>
<td>Radioactive material contamination (eyes, hands, wrists, skin)</td>
<td>Lab coat</td>
<td>Personal radiation badge as appropriate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Survey meter as appropriate</td>
<td>Bench-top radiation shielding as appropriate</td>
</tr>
<tr>
<td>Performing an iodination with volatile radioactive sodium iodide inside an approved radioiodine fume hood</td>
<td>Contamination of personal clothing (shoes, body)</td>
<td>Shoe covers</td>
<td>Safety glasses</td>
</tr>
<tr>
<td></td>
<td>Radioactive material contamination (eyes, hands, wrists, skin)</td>
<td>Double gloves</td>
<td>Sleeve covers</td>
</tr>
<tr>
<td></td>
<td>Inhalation of volatile material (respiratory)</td>
<td>Lab coat</td>
<td>Personal radiation badge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Survey meter with scintillation probe</td>
<td>Benchtop radiation shielding</td>
</tr>
<tr>
<td>Applies</td>
<td>Activities/Jobs/Tasks</td>
<td>Potential Exposures Addressed by PPE</td>
<td>Personal Protective Equipment Requirements</td>
</tr>
<tr>
<td>---------</td>
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<td>--------------------------------------------</td>
</tr>
</tbody>
</table>
| Working at a microscope in the laboratory | • Hazard material contamination (hands)  
  • Contamination of personal clothing (body) | • (If necessary, safety glasses may be temporarily removed while viewing materials via a microscope)  
  • Gloves if touching potentially contaminated material  
  • Lab coat or gown |  |
| Operating analytical or diagnostic x-ray generating equipment (fluoroscopy, XRD, XRF, patient procedures, etc.) | • Radiation exposure (body)  
  • If patient or human subject, standard precautions  
  • If laboratory animals, allergens (respiratory or transfer to mucous membranes of the eyes, nose or mouth) | • Lead apron or use of structural radiation shielding as appropriate  
  • Personal radiation badge and ring if assigned  
  • Survey Meter as appropriate  
  • Gloves, as appropriate  
  • Lab coat, gown or approved uniform, as appropriate |  |
| Working with open table Class 3B or 4 Lasers | • Ocular and skin exposure (eyes, face, hands, body) | • Protective eyewear of proper optical density  
  • Face shield for UV Lasers  
  • Appropriate gloves for UV lasers  
  • Lab coat for UV lasers  
  • No jewelry or reflective items worn |  |

Biohazard experiments are classified based on risk. The starting point for risk assessment is the assignment of a biohazard to a specific Risk Group. There are 4 Risk Groups (RGs) based on risk to the individual and the community. RG1 is the lowest risk and RG4 is the highest. Risk Group assignments for human pathogens can be accessed at: [http://www.absa.org/riskgroups/index.html](http://www.absa.org/riskgroups/index.html)

For other experiments, researchers can refer to the Gradations of Risk Table referenced in this document.
<table>
<thead>
<tr>
<th>Applies</th>
<th>Activities/Jobs/Tasks</th>
<th>Potential Exposures Addressed by PPE</th>
<th>Personal Protective Equipment Requirements</th>
</tr>
</thead>
</table>
| Working with human blood, tissues, body fluids, human cell lines, or Risk Group 2 bloodborne pathogens, utilizing Universal Precautions and BSL2 containment. | • Potentially infectious materials by splash (to mucous membranes of the eyes, nose or mouth, or through non-intact skin)  
• Puncture by contaminated sharps (skin—percutaneous) | • Safety glasses  
• Mask or face shield if splashing is possible  
• Gloves—nitrile exam and/or cut-resistant  
• Lab coat or gown  
• Surgical mask or respirator, if specified  
• Additional PPE may be required based on risk to the individual | |
| Experiments involving Risk Group 2 agents, that represent a moderate risk to the individual and may cause disease of varying severity. Examples of Risk Group 2 agents include *Plasmodium falciparum*, *Salmonella typhimurium*, Herpes Simplex Virus and *Cryptococcus neoformans* | • Exposure to agent (eyes, hands, skin)  
• Puncture by contaminated sharps (skin—percutaneous)  
• Ingestion (eyes, nose or mouth)  
• Aerosol production can create potential risk of inhalation and contamination of surrounding surfaces (respiratory) | • Safety glasses  
• Gloves  
• Lab coat or gown  
• Respirator, if specified  
• Additional PPE may be required based on risk to the individual  
• Confine aerosols as close as possible to their point of generation  
• Use a biosafety cabinet or other engineering control | |
| Experiments with Risk Group 3 agents (i.e. West Nile Virus, *Mycobacterium tuberculosis*, *Histoplasma capsulatum*) in cell culture or laboratory animals | • All RG2 routes of exposure may be applicable (eyes, nose, mouth, hands, respiratory, skin)  
• Inhalation is of particular concern for pathogens classified at Risk Group 3 (respiratory) | • All work with RG3 agents must be conducted under primary containment using BSL3 containment practices. Specialized laboratories are required for this work.  
• **All procedures with RG3 agents must be approved by the Yale Biological Safety Committee**  
• Full face protection—face shield or safety glasses and mask  
• Gloves—exam, two pairs  
• Gown—back-fastening  
• Additional PPE may be required based on risk to the individual, such as respiratory protection, protective sleeve covers, booties, jump suits, etc. | |
<table>
<thead>
<tr>
<th>Applies</th>
<th>Activities/Jobs/Tasks</th>
<th>Potential Exposures Addressed by PPE</th>
<th>Personal Protective Equipment Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performing work with Risk Group 4 agents (i.e. Ebola virus, Marburg virus) or work that requires BSL4 containment. Risk Group 4 agents represent a very high risk to the individual and are also a risk to the community.</td>
<td>• All routes of exposure (percutaneous, inhalation, ingestion, and via facial mucous membranes) may be involved with these experiments.</td>
<td>• Work with Risk Group 4 Agents is not allowed at Yale University.</td>
</tr>
</tbody>
</table>

**CERTIFICATION STATEMENT**
I have performed a PPE hazard assessment of the work being conducted in areas under my responsibility and will implement requirements based on this assessment.

Print Name of Principal Investigator/Lab Manager/Supervisor/Instructor:  

<table>
<thead>
<tr>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
</table>

Note any proposed exceptions or alternate PPE requirements here, and forward to EHS for approval. EHS approval is required before implementing any less stringent exceptions or alternate PPE requirements.

<table>
<thead>
<tr>
<th>Signature of EHS Approver</th>
<th>Date of Approval</th>
</tr>
</thead>
</table>
APPENDIX I  HIGHLY REACTIVE COMPOUNDS AND STRONG OXIDIZERS

Examples of potentially explosive and explosive compounds include:

Potentially Explosive Compounds (PEC)

<table>
<thead>
<tr>
<th>Acetyl peroxide</th>
<th>Acetylene</th>
<th>Ammonium nitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium perchlorate</td>
<td>Ammonium picrate</td>
<td>Barium azide</td>
</tr>
<tr>
<td>Benzoyl peroxide</td>
<td>Bromopropylene</td>
<td>Butanone peroxide</td>
</tr>
<tr>
<td>Cumene peroxide</td>
<td>Diazodinitrophenol</td>
<td>Dinitrophenol</td>
</tr>
<tr>
<td>Dinitrophenylhydrazine</td>
<td>Dinitroresorcinol</td>
<td>Dipicryl amine</td>
</tr>
<tr>
<td>Dipicryl sulphide</td>
<td>Dodecanoyl peroxide</td>
<td>Ethylene oxide</td>
</tr>
<tr>
<td>Heavy metal azides</td>
<td>Lauric peroxide</td>
<td>Lead azide</td>
</tr>
<tr>
<td>Lithium azide</td>
<td>Methyl ethyl ketone peroxide</td>
<td>Mercury azide</td>
</tr>
<tr>
<td>Mercury fulminate</td>
<td>Nitrocellulose</td>
<td>Nitrogen trifluoride</td>
</tr>
<tr>
<td>Nitrogen trioxide</td>
<td>Nitroglycerine</td>
<td>Nitroguanidine</td>
</tr>
<tr>
<td>Nitromethane</td>
<td>Nitrourea</td>
<td>Organic azides</td>
</tr>
<tr>
<td>Picramide</td>
<td>Picric acid</td>
<td>Picryl chloride</td>
</tr>
<tr>
<td>Picryl sulphonic acid</td>
<td>Potassium azide</td>
<td>Propargyl bromide (neat)</td>
</tr>
<tr>
<td>Silver fulminate</td>
<td>Sodium azide</td>
<td>Sodium dinitrophenate</td>
</tr>
<tr>
<td>Succinic peroxide</td>
<td>Tetranitroaniline</td>
<td>Trinitroaniline</td>
</tr>
<tr>
<td>Trinitroanisole</td>
<td>Trinitrobenzene</td>
<td>Trinitrobenzenesulfonic acid</td>
</tr>
<tr>
<td>Trinitrobenzoic acid</td>
<td>Trinitroresol</td>
<td>Trinitronaphthalene</td>
</tr>
<tr>
<td>Trinitrophenol</td>
<td>Trinitroresorcinol</td>
<td>Trinitrotoluene</td>
</tr>
<tr>
<td>Urea nitrate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Potentially Explosive Compound Classes

<table>
<thead>
<tr>
<th>Acetylene (-C=C-)</th>
<th>Acyl hypohalites (RCO-OX)</th>
<th>Azide Organic (R-N3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azide Metal (M-N3)</td>
<td>Azido (-N=N-1)</td>
<td>Diazo (-N=N)</td>
</tr>
<tr>
<td>Diazosulphide (-N=N-S-N=N-)</td>
<td>Diazonium salts (R-N2+)</td>
<td>Fulminate (-CNO)</td>
</tr>
<tr>
<td>Halogen Amine (-N-X)</td>
<td>Nitrate (-ONO2)</td>
<td>Nitro (-NO2)</td>
</tr>
<tr>
<td>Aromatic or Aliphatic Nitramine (-N-NO2)</td>
<td>Nitrite (-ONO)</td>
<td>Nitroso (-NO)</td>
</tr>
<tr>
<td>Ozonides</td>
<td>Peroxyacids (-CO-O-O-H)</td>
<td>Peroxide (-O-O-)</td>
</tr>
<tr>
<td>Hydroperoxide (-O-O-H)</td>
<td>Metal peroxide (M-O-O-M)</td>
<td></td>
</tr>
</tbody>
</table>

Explosive Salts

<table>
<thead>
<tr>
<th>Bromate salts (BrO3-)</th>
<th>Chlorate salts (ClO3-)</th>
<th>Chlorite salts (ClO2-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perchlorate salts (ClO4-)</td>
<td>Picroxate salts (2,4,6-trinitrophenoxide)</td>
<td>Picromate salts (2-amino-4,6-dinitrophenoxide)</td>
</tr>
<tr>
<td>Hypohalite salts (XO-)</td>
<td>Iodate salts (IO3-)</td>
<td></td>
</tr>
</tbody>
</table>

Examples of strong oxidizers include:

- Ammonium perchlorate (Class 4)
- Ammonium permanganate (Class 4)
- Chromic acid (Class 2)
- Hydrogen peroxide (>27.5-52% Class 2, >52-91% Class 3)
- Magnesium peroxide (Class 1)
- Nitric Acid (≤40% Class 1, >40-86% Class 2)
- Perchloric acid (>50-60% Class 2, >60-72% Class 3, >72% Class 4)
- Potassium bromate (Class 3)
- Potassium chlorate (Class 3)
- Potassium peroxide (Class 2)
- Sodium chlorate (Class 3)
- Sodium chlorite (>40% Class 3)
- Sodium perchlorate (Class 2)
Examples of incompatible chemicals

<table>
<thead>
<tr>
<th>CHEMICAL</th>
<th>KEEP OUT OF CONTACT WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic Acid</td>
<td>Chromic acid, nitric acid hydroxyl compounds, ethylene, glycol, perchloric acid, peroxides, permanganates</td>
</tr>
<tr>
<td>Acetone</td>
<td>Concentrated nitric and sulfuric acid mixtures</td>
</tr>
<tr>
<td>Acetylene</td>
<td>Chlorine, bromine, copper, fluorine, silver, mercury</td>
</tr>
<tr>
<td>Alkali Metals</td>
<td>Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, the halogens</td>
</tr>
<tr>
<td>Ammonia, anhydrous</td>
<td>Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid</td>
</tr>
<tr>
<td>Ammonium Nitrate</td>
<td>Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials</td>
</tr>
<tr>
<td>Aniline</td>
<td>Nitric acid, hydrogen peroxide</td>
</tr>
<tr>
<td>Arsenical materials</td>
<td>Any reducing agent</td>
</tr>
<tr>
<td>Azides</td>
<td>Acids</td>
</tr>
<tr>
<td>Bromine</td>
<td>Same as chlorine</td>
</tr>
<tr>
<td>Calcium Oxide</td>
<td>Water</td>
</tr>
<tr>
<td>Carbon (activated)</td>
<td>Calcium hypochlorite, all oxidizing agents.</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>Sodium</td>
</tr>
<tr>
<td>Chlorates</td>
<td>Ammonium salts, acids, metal powders, sulfur, finely divided organic or combustible materials</td>
</tr>
<tr>
<td>Chromic Acid</td>
<td>Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids in general</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals</td>
</tr>
<tr>
<td>Chlorine Dioxide</td>
<td>Ammonia, methane, phoshine, hydrogen sulfide</td>
</tr>
<tr>
<td>Copper</td>
<td>Acetylene, hydrogen peroxide</td>
</tr>
<tr>
<td>Cumene Hydroperoxide</td>
<td>Acids, organic or inorganic</td>
</tr>
<tr>
<td>Cyanides</td>
<td>Acids</td>
</tr>
<tr>
<td>Flammable Liquids</td>
<td>Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>Fluorine, chlorine, bromine, chromic acid, sodium peroxide</td>
</tr>
<tr>
<td>Hydrocyanic Acid</td>
<td>Nitric acid, alkali</td>
</tr>
<tr>
<td>Hydrofluoric Acid</td>
<td>Ammonia, aqueous or anhydrous</td>
</tr>
<tr>
<td>Hydrogen Peroxide</td>
<td>Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidizing gases</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>Fuming nitric acid, oxidizing gases, acetylene, ammonia (aqueous or anhydrous), hydrogen</td>
</tr>
<tr>
<td>Hypochlorites</td>
<td>Acids, activated carbon</td>
</tr>
<tr>
<td>Iodine</td>
<td>Acetylene, ammonia (aqueous or anhydrous), hydrogen</td>
</tr>
<tr>
<td>Mercury</td>
<td>Acetylene, fulminic acid, ammonia</td>
</tr>
<tr>
<td>CHEMICAL</td>
<td>KEEP OUT OF CONTACT WITH</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Nitrates</td>
<td>Sulfuric acid</td>
</tr>
<tr>
<td>Nitric Acid (concentrated)</td>
<td>Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases</td>
</tr>
<tr>
<td>Nitrites</td>
<td>Acids</td>
</tr>
<tr>
<td>Nitroparaffins</td>
<td>Inorganic bases, amines</td>
</tr>
<tr>
<td>Oxalic Acid</td>
<td>Silver, mercury</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Oils, grease, hydrogen; flammable liquids, solids, or gases</td>
</tr>
<tr>
<td>Perchloric Acid</td>
<td>Acetic anhydride, bismuth and its alloys, alcohol, paper, wood</td>
</tr>
<tr>
<td>Peroxides, organic</td>
<td>Acids (organic or mineral), avoid friction, store cold</td>
</tr>
<tr>
<td>Phosphorus (white)</td>
<td>Air, oxygen, alkalies, reducing agents</td>
</tr>
<tr>
<td>Potassium</td>
<td>Carbon tetrachloride, carbon dioxide, water</td>
</tr>
<tr>
<td>Potassium Chlorate</td>
<td>Sulfuric and other acids</td>
</tr>
<tr>
<td>Potassium Permanganate</td>
<td>Glycerin, ethylene glycol, benzaldehyde, sulfuric acid</td>
</tr>
<tr>
<td>Selenides</td>
<td>Reducing agents</td>
</tr>
<tr>
<td>Silver</td>
<td>Acetylene, oxalic acid, tartaric acid, ammonium compounds</td>
</tr>
<tr>
<td>Sodium</td>
<td>Carbon tetrachloride, carbon dioxide, water</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>Ammonium nitrate and other ammonium salts</td>
</tr>
<tr>
<td>Sodium Peroxide</td>
<td>Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural</td>
</tr>
<tr>
<td>Sulfides</td>
<td>Acids</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>Potassium chlorate, potassium perchlorate, potassium permanganate (or compounds with similar light metals, such as sodium, lithium, etc.)</td>
</tr>
<tr>
<td>Tellurides</td>
<td>Reducing agents</td>
</tr>
</tbody>
</table>

(From Manufacturing Chemists' Association, Guide for Safety in the Chemical Laboratory, pp. 215-217.)
This standard operating procedure (SOP) is intended to provide general guidance on how to safely work with flammable liquids. This SOP is generic in nature and only addresses safety issues specific to flammable liquids. In some instances, several general use SOPs may be applicable for a specific chemical.

The National Fire Protection Agency (NFPA) considers any chemical to be flammable if it has a flashpoint below 37.8°C (100°F). There are three classes of flammable liquids per the NFPA:

- **Class IA.** Liquids having a flash point below 73°F (23°C) and having a boiling point below 100°F (38°C).
- **Class IB.** Liquids having a flash point below 73°F (23°C) and having a boiling point above 100°F (38°C).
- **Class IC.** Liquids having a flash point at or above 73°F (23°C) and below 100°F (38°C)

OSHA defines a flammable liquid as any liquid having a flashpoint at or below 199.4 °F (93 °C). Flammable liquids are divided into four categories as follows:

- **Category 1** shall include liquids having flashpoints below 73.4 °F (23 °C) and having a boiling point at or below 95 °F (35 °C).
- **Category 2** shall include liquids having flashpoints below 73.4 °F (23 °C) and having a boiling point above 95 °F (35 °C).
- **Category 3** shall include liquids having flashpoints at or above 73.4 °F (23 °C) and at or below 140 °F (60 °C). When a Category 3 liquid with a flashpoint at or above 100 °F (37.8 °C) is heated for use to within 30 °F (16.7 °C) of its flashpoint, it shall be handled in accordance with the requirements for a Category 3 liquid with a flashpoint below 100 °F (37.8 °C).
- **Category 4** shall include liquids having flashpoints above 140 °F (60 °C) and at or below 199.4 °F (93 °C). When a Category 4 flammable liquid is heated for use to within 30 °F (16.7 °C) of its flashpoint, it shall be handled in accordance with the requirements for a Category 3 liquid with a flashpoint at or above 100 °F (37.8 °C).

**Examples of flammable liquids include:**

- Acetone
- Alcohols
- Benzene
- Ether
- Hexane
- Hydrazine
- Toluene
- Xylene
Potential Hazards/Toxicity

Physical Hazards
Flammable liquids usually have high vapor pressures at room temperature and their vapors, mixed with air at the appropriate ratio, can ignite and burn. As with all solvents, their vapor pressure increases with temperature and therefore as temperatures increase, they become more hazardous.

The concentrated vapors of flammable liquids may be heavier than air and can cause vapor trails which can travel to reach an ignition source, resulting in a flashback fire. Fire can also result from reactions between flammables or combustibles and oxidizers.

Health Hazards
In addition to the fire hazard, many flammable liquids pose health hazards as well. Effects from acute inhalation exposures range from irritation to CNS depression, nausea and dizziness. In extreme situations, coma can result. Chronic exposures may lead to live or kidney damage. Skin absorption can lead to similar long term effects as inhalation exposures. Skin contact with solvents may result in defatting and drying of the skin. Some flammable liquids also have additional health hazards, i.e., benzene is also a known human carcinogen.

As the hazards may vary by compound, users must familiarize themselves with the specific hazards of the compounds they are working with, which can be found on the chemical’s Safety Data Sheet (SDS). SDSs are available through the ChemWatch link on Yale’s EHS webpage (ehs.yale.edu).

Personal Protective Equipment (PPE)
*The University’s Personal Protective Equipment Policy can be found here: [http://ehs.yale.edu/PPEPolicy](http://ehs.yale.edu/PPEPolicy)*

Eye Protection
Safety glasses must be worn whenever handling flammable liquids. When there is the potential for splashes, goggles and/or a faceshield must be worn.

Hand Protection
Gloves must be worn when handling flammable liquids. Exam style nitrile gloves (minimum 4mil thickness) are generally adequate for handling these compounds in laboratory settings when skin contact is unlikely. However, if skin contact is likely or larger amounts are being used, then a utility grade glove should be worn over the exam style nitrile. To ensure that the appropriate utility grade glove is selected, use one of the glove selection guides below or contact EHS.


Skin and Body Protection
Long pants or clothing that covers the body to the ankles and closed-toe solid top shoes must be worn when handling flammable liquids. Lab coats must be worn. When working with large amounts of flammable liquids, a 100% cotton or flame resistant lab coat is preferred. For flammable liquids that pose health hazards through dermal absorption, additional protective clothing (i.e., apron, oversleeves) may be appropriate where chemical contact with the skin is likely.

Engineering Controls

Fume Hood
Fume hoods, or other locally exhausted ventilation, should be used whenever handling flammable liquids. Local exhaust ventilation is particularly important when using larger...
quantities (>500ml) or when flammables are heated or at increased pressure.

**Storage/Handling**

- Minimize the storage of flammable liquids outside flammable rated storage cabinets. The volume stored outside of rated cabinets and safety cans must be <10 gallons per laboratory.
- 5-gallon cans of flammable liquids must be stored inside flammable rated cabinets.
- Refrigerators used for the storage of flammable liquids must be designed/rated for this purpose.
- Keep flammables segregated from incompatible materials, including oxidizers.
- Store at/below eye level (~5 feet).
- Metal surfaces or containers through which flammable liquids flow must be properly grounded, to discharge static electricity.
- Large quantities (≥5 gallons) of flammable liquids must be handled using spark-free tools in areas free of ignition sources, including spark emitting motors and equipment.
- Never heat flammable liquids by using an open flame. Use steam baths, water baths, oils baths, heating mantles or hot air baths.
- If flammable liquids must be heated in an oven, make sure the oven is appropriately designed for flammable liquids (no internal ignition sources and/or vented mechanically).
- When heating flammable liquids, ensure that the autoignition temperature of the solvent is above the oven temperature or its internal elements.
- Do not distill flammable liquids under reduced pressure.

**Waste Disposal**

Most flammable liquids must be collected as hazardous waste. Some dilute aqueous solutions (<5%) of low molecular weight biodegradable organic chemicals may be appropriate for sanitary sewer discharge, i.e., alcohols, ethylene glycol, and glycerol. Check the “Management of Hazardous Waste” manual for a more comprehensive list. In addition, all items contaminated with a flammable liquid which is also acutely toxic (P-Listed) must be collected as hazardous waste, e.g.: carbon disulfide. This includes reagent bottles, weigh boats, pipette tips, kimwipes, and other similar items that have come into contact with these compounds.

**Emergency Procedures**

**Fire Extinguishers**
Both ABC dry powder and carbon dioxide extinguishers are appropriate for most fires involving acutely toxic compounds.

**Eyewash/Safety Showers**
An ANSI approved eyewash station that can provide quick drenching or flushing of the eyes must be immediately available within 10 seconds travel time for emergency use. An ANSI approved safety drench shower must also be available within 10 seconds travel time from where these compounds are used. Ensure the locations of the eyewashes and safety showers, and how to activate them, are known prior to an emergency.

**First Aid Procedures**

**If inhaled**
Remove to fresh air. Follow up with Acute Care or Employee Health as appropriate (203-432-0123).

**In case of skin contact**
Go to the nearest emergency shower if contaminated. Yell for assistance and rinse for 15 minutes, removing all articles of clothing to ensure contaminate is completely removed. Follow up at Acute Care/Employee Health as appropriate (203-432-0123).

**In case of eye contact**
Go to the nearest emergency eyewash. Yell for assistance and rinse for 15 minutes. Follow up at Acute Care/Employee Health as appropriate (203-432-0123).
Spills
Small Spill
If a small spill of a low toxicity flammable liquid occurs, lab personnel should be able to safely clean it up by following standard spill clean up procedures:

- Alert people in immediate area of spill
- Increase ventilation in area of spill (open fume hood sashes)
- Wear personal protective equipment, including utility grade gloves
- Confine/adsorb spill with spill clean up pads or absorbent
- Collect residue, place in container, label container, and dispose of as hazardous waste
- Clean spill area with soap and water

Larger Spill/Any spill outside a fume hood

- Call EHS for emergency assistance (203-785-3555)
- Evacuate the spill area
- Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering
- Stay nearby until emergency personnel arrive and provide them with information on the chemicals involved

Please list the compounds used by this research group which are covered by this procedure. The list should also include the building/room where they are used.

Lab Specific Protocol/Procedure:

Principal Investigator’s Signature/Date
APPENDIX L  EXPLOSIVE AND POTENTIALLY EXPLOSIVE COMPOUNDS SOP

Standard Operating Procedure

POTENTIALLY EXPLOSIVE AND EXPLOSIVE COMPOUNDS*

This standard operating procedure (SOP) is intended to provide general guidance on how to safely work with compounds which are explosive or potentially explosive. This SOP is generic in nature and only addresses safety issues specific to these materials. In some instances, several general use SOPs may be applicable for a specific chemical.

An explosive is any chemical compound or mechanical mixture that, when subjected to heat, impact, friction, detonation, or other suitable initiation, undergoes rapid chemical change, evolving large volumes of gases that exert pressure on the surrounding medium. The term applies to materials that either detonate or deflagrate. Heat, light, mechanical shock and certain catalysts initiate explosive reactions.

Examples of potentially explosive and explosive compounds include:

Potentially Explosive Compounds (PEC)

<table>
<thead>
<tr>
<th>Acetyl peroxide</th>
<th>Acetylene</th>
<th>Ammonium nitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium perchlorate</td>
<td>Ammonium picrate</td>
<td>Barium azide</td>
</tr>
<tr>
<td>Benzoyl peroxide</td>
<td>Bromopropyne</td>
<td>Butanone peroxide</td>
</tr>
<tr>
<td>Cumene peroxide</td>
<td>Diazodinitrophenol</td>
<td>Dinitrophenol</td>
</tr>
<tr>
<td>Dinitrophenylhydrazine</td>
<td>Dinitroresorcinol</td>
<td>Dipicryl amine</td>
</tr>
<tr>
<td>Dipicryl sulphone</td>
<td>Dodecanoyl peroxide</td>
<td>Ethylene oxide</td>
</tr>
<tr>
<td>Heavy metal azides</td>
<td>Lauric peroxide</td>
<td>Lead azide</td>
</tr>
<tr>
<td>Lithium azide</td>
<td>Methyl ethyl ketone peroxide</td>
<td>Mercury azide</td>
</tr>
<tr>
<td>Mercury fulminate</td>
<td>Nitrocellulose</td>
<td>Nitrogen trifluoride</td>
</tr>
<tr>
<td>Nitrogen trioxide</td>
<td>Nitroglycerine</td>
<td>Nitroguanidine</td>
</tr>
<tr>
<td>Nitromethane</td>
<td>Nitrourea</td>
<td>Organic azides</td>
</tr>
<tr>
<td>Picramide</td>
<td>Picric acid</td>
<td>Picryl chloride</td>
</tr>
<tr>
<td>Picryl sulphonic acid</td>
<td>Potassium azide</td>
<td>Propargyl bromide (neat)</td>
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<td>Silver fulminate</td>
<td>Sodium azide</td>
<td>Sodium dimethoxide</td>
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<td>Tetranitroaniline</td>
<td>Trinitroaniline</td>
</tr>
<tr>
<td>Trinitroanisole</td>
<td>Trinitrobenzene</td>
<td>Trinitrobenzenesulphonic acid</td>
</tr>
<tr>
<td>Trinitrobenzoic acid</td>
<td>Trinitrocresol</td>
<td>Trinitronaphthalene</td>
</tr>
<tr>
<td>Trinitrophenol</td>
<td>Trinitroresorcinol</td>
<td>Trinitrotoluene</td>
</tr>
<tr>
<td>Urea nitrate</td>
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</tr>
</tbody>
</table>

Potentially Explosive Compound Classes

<table>
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<tr>
<th>Acetylene (C=C-)</th>
<th>Acyl hypohalites (RCO-OX)</th>
<th>Azide Organic (R-N3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azide Metal (M-N3)</td>
<td>Azo (==N=N)</td>
<td>Diazoo (==N-N)</td>
</tr>
<tr>
<td>Diazosulphide (=N=N=S-N-N=)</td>
<td>Diazonium salts (R-N2+)</td>
<td>Fulminate (=ONO)</td>
</tr>
<tr>
<td>Halogen Amine (=N-X)</td>
<td>Nitrate (=ONO2)</td>
<td>Nitro (=NO2)</td>
</tr>
<tr>
<td>Aromatic or Aliphatic Nitramine (=N-NO2) (=NH-NO2)</td>
<td>Nitrite (=ONO)</td>
<td>Nitroso (=NO)</td>
</tr>
<tr>
<td>Ozonides</td>
<td>Peracids (=CO-O-O-H)</td>
<td>Peroxide (=O=O-)</td>
</tr>
<tr>
<td>Hydroperoxide (=O=H)</td>
<td>Metal peroxide (M-O-O-M)</td>
<td></td>
</tr>
</tbody>
</table>

Explosive Salts

<table>
<thead>
<tr>
<th>Bromate salts (BrO3-)</th>
<th>Chlorate salts (ClO3-)</th>
<th>Chlorite salts (ClO2-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perchlorate salts (ClO4-)</td>
<td>Picate salts (2,4,6-trinitrophenoxide)</td>
<td>Picramate salts (2-amino-4,6-dinitrophenoxide)</td>
</tr>
<tr>
<td>Hypohalite salts (XO-)</td>
<td>Iodate salts (IO3-)</td>
<td></td>
</tr>
</tbody>
</table>

Potential Hazards/Toxicity
The most obvious hazard of potentially explosive and explosive compounds stems from the physical injuries that may occur from flying debris (metal, glass, ceramic, etc.) and burns due to fires that might accompany or follow the explosion.

Some of these compounds may also cause acute and chronic health effects.

Users must familiarize themselves with the specific hazards and toxicity of the compounds they are working with, which can be found on the chemical’s Safety Data Sheet (SDS). SDSs are available through the ChemWatch link on Yale’s EHS webpage (ehs.yale.edu).

**Personal Protective Equipment (PPE)**

The University’s Personal Protective Equipment Policy can be found here: [http://ehs.yale.edu/PPEPolicy](http://ehs.yale.edu/PPEPolicy)

**Eye Protection**

Goggles and faceshield must be worn whenever handling these compounds.

**Hand Protection**

Gloves must be worn when handling PECs and explosive compounds. Exam style nitrile gloves (minimum 4mil thickness) are generally adequate for handling these compounds in laboratory settings when working with the solids or when skin contact is unlikely with solutions. However, if skin contact with the solution is likely or larger amounts are being used, then a utility grade glove should be worn over the exam style nitrile. In many cases, a utility grade nitrile or neoprene glove is appropriate, but verify by using one of the glove guides below or contacting EHS.


**Skin and Body Protection**

Long pants or clothing that covers the body to the ankles and closed-toe solid top shoes must be worn when handling PECs and explosive compounds. Lab coats must be worn. If the compound also poses a health hazards through dermal absorption, additional protective clothing (i.e., apron, oversleeves) may be appropriate where chemical contact with the skin is likely.

**Engineering Controls**

**Fume Hood**

Fume hoods, or other locally exhausted ventilation, must be used whenever handling PECs and explosive compounds.

**Portable Blast Shield**

While a blast shield is recommended whenever working with potentially explosive compounds, it is required under the following conditions:

- When a reaction is attempted for the first time (small quantities of reactants should be used to minimize hazards);
- When a familiar reaction is carried out on a larger than usual scale (i.e., 5-10 times more material); or
- When operations are carried out under non-ambient conditions.

**Storage/Handling**

- Store in designated cabinets and not on benches or shelves. PECs which are flammable should be stored in cabinets or refrigerators which are rated for flammable storage.
- Label incoming containers with the date of receipt. Do not use reactive materials past their expiration date.
• Exercise due care when handling peroxide formers. Visually inspect bottle cap and threads of container (without handling) for presence of organic peroxide crystals.
• The scale of work is critical. It should be done at the smallest scale possible (e.g., mmole) and scaled up only with the authorization of the Principal Investigator.
• For those chemicals that deflagrate, eliminate sources of confinement if possible.
• Only those chemicals involved in the operation should be in the vicinity of the work being done.
• Identify and eliminate sources of static discharge since this can be an initiating force for some explosives. Low humidity environments also increase the potential for static.
• Conduct transfers and other operations with compatible tools and equipment. For example, some explosives can form more sensitive compounds when exposed to metal and especially heavy metals. For those chemicals, non-metal tools and equipment should be used.
• Keep the work area, tools and equipment clean. Do not allow explosives to build up. Use non-static wipes or brushes or use appropriate wet methods to clean handling areas. Do not scrape explosives from surfaces.
• Do not attempt to crush or grind an explosive or apply other pressure to it unless it is explicitly known that the explosive is not sensitive to it.

Waste Disposal
Collect PECs and explosive compounds as hazardous waste. Where possible dilute explosive wastes in a safe solvent, since many explosives are more stable when dilute. Keep explosive wastes separate from other wastes.

Emergency Procedures

Fire Extinguishers
Both ABC dry powder and carbon dioxide extinguishers are appropriate for most fires involving PECs and explosive compounds.

Eyewash/Safety Showers
An ANSI approved eyewash station that can provide quick drenching or flushing of the eyes must be immediately available within 10 seconds travel time for emergency use. An ANSI approved safety drench shower must also be available within 10 seconds travel time from where these compounds are used. Ensure the locations of the eyewashes and safety showers, and how to activate them, are known prior to an emergency.

First Aid Procedures

If inhaled
Remove to fresh air. Follow up with Acute Care or Employee Health as appropriate (203-432-0123).

In case of skin contact
Go to the nearest emergency shower if contaminated. Yell for assistance and rinse for 15 minutes, removing all articles of clothing to ensure contaminant is completely removed. Follow up at Acute Care/Employee Health as appropriate (203-432-0123).

In case of eye contact
Go to the nearest emergency eyewash. Yell for assistance and rinse for 15 minutes. Follow up at Acute Care/Employee Health (203-432-0123).

Explosion
If an explosion occurs, determine if any injuries have occurred. If immediate medical attention is necessary, call 911. After assisting injured persons, secure the area and call EHS for emergency assistance (203-785-3555).

Spills
Small Spill
If a small occurs, lab personnel should be able to safely clean it up by following standard spill clean up procedures:

- Alert people in immediate area of spill
- Increase ventilation in area of spill (open fume hood sashes)
- Wear personal protective equipment, including utility grade gloves
- Confine/adsorb spill with spill clean up pads or absorbent
- Collect residue, place in container, label container, and dispose of as hazardous waste
- Clean spill area with soap and water

**Larger Spill/Any spill outside a fume hood**

- Call EHS for emergency assistance (203-785-3555)
- Evacuate the spill area
- Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering
- Stay nearby until emergency personnel arrive and provide them with information on the chemicals involved

**Please list the compounds used by this research group which are covered by this procedure. The list should also include the building/room where they are used.**

<table>
<thead>
<tr>
<th>Compounds Used</th>
<th>Building/Room</th>
</tr>
</thead>
</table>

**Lab Specific Protocol/Procedure:**

Principal Investigator’s Signature/Date
Standard Operating Procedure

STRONG OXIDIZERS

This standard operating procedure (SOP) is intended to provide general guidance on how to safely work with compounds which are strong oxidizers. This SOP is generic in nature and only addresses safety issues specific to these materials. In some instances, several general use SOPs may be applicable for a specific chemical.

Oxidizing chemicals are materials that promote/support combustion or spontaneously evolve oxygen at room temperature or with slight heating. This class of chemicals includes peroxides, chlorates, perchlorates, nitrates, and permanganates. Strong oxidizers are capable of forming explosive mixtures when mixed with combustible, organic or easily oxidized materials.

The NFPA defines four categories of strong oxidizers, divided by the severity of risk when mixed with other compounds:

- Class 1. An oxidizer that does not moderately increase the burn rate of another material.
- Class 2. An oxidizer that will moderately increase the burn rate.
- Class 3. An oxidizer that will cause a severe increase in burn rate.
- Class 4. An oxidizer that has the potential to lead to an explosive oxidation when combined with other materials.

Examples of strong oxidizers include:

- Ammonium perchlorate (Class 4)
- Ammonium permanganate (Class 4)
- Chromic acid (Class 2)
- Hydrogen peroxide (>27.5-52% Class 2, >52-91% Class 3)
- Mangesium peroxide (Class 1)
- Nitric Acid (≤40% Class 1, >40-86% Class 2)
- Perchloric acid (>50-60% Class 2, >60-72% Class 3, >72% Class 4)
- Potassium bromate (Class 3)
- Potassium chloride (Class 3)
- Potassium peroxide (Class 2)
- Sodium chlorate (Class 3)
- Sodium chlorite (>40% Class 3)
- Sodium perchlorate (Class 2)

Potential Hazards/Toxicity
Physical Hazards
Strong oxidizing agents can present fire and explosive hazards. This hazard is highest when there is a possibility of an oxidizing agent coming in contact with a reducing agent, a fuel, or some other combustible.

Solid oxidizers in solution may be too dilute to react with combustible materials to produce a fire. However, if a combustible material (e.g., a paper towel, lab coat, lab matting) is contaminated with a solution containing an oxidizer, as the solution dries, the oxidizer is concentrated. This can cause the combustible material to spontaneously ignite and burn intensely.

Toxicity of Oxidizing Compounds
The combustion products of oxidizer-fed fires are generally much more toxic than the combustion products of the combustible material itself in air. For example, methane (i.e., natural gas) burned in air will produce carbon dioxide and water. Burned in a chlorine atmosphere, the combustion products are hydrogen chloride gas and carbon tetrachloride vapor. Inhaled, hydrogen chloride gas will go into solution as hydrochloric acid and corrode lung tissue and other mucous membranes. This can result in chemical pulmonary edema with symptoms not becoming evident for several hours. Other oxidizers have similar hazards.

Since the purpose of oxidizers is to oxidize, tissues such as lung, skin and eyes are at risk. The hazards to tissues from oxidizers will vary depending on the oxidizer and its concentration. Skin exposure can result in dangerous burns, but dermatitis (i.e., drying of the skin) is more common. Eyes are much more sensitive to exposure.

Users must familiarize themselves with the specific hazards of the compounds they are working with, which can be found on the chemical's Safety Data Sheet (SDS). SDSs are available through the ChemWatch link on Yale's EHS webpage (ehs.yale.edu).

Personal Protective Equipment (PPE)
The University's Personal Protective Equipment Policy can be found here: http://ehs.yale.edu/PPEPolicy

Eye Protection
Safety glasses must be worn whenever handling oxidizing chemicals. When there is the potential for splashes, goggles must be worn.

Hand Protection
Gloves must be worn when handling oxidizing chemicals. Exam style nitrile gloves (minimum 4mil thickness) should be adequate for handling small quantities of these compounds in general laboratory settings. However, if skin contact is likely or large amounts are being used, then a utility grade neoprene or nitrile glove should be worn over the exam style nitrile.

Skin and Body Protection
Long pants or clothing that covers the body to the ankles and closed-toe solid top shoes must be worn when handling these compounds. Lab coats must be worn. Additional protective clothing (i.e., face shield, apron, oversleeves) is appropriate where chemical contact with the skin is likely.

Engineering Controls

Fume Hood
Fume hoods, or other locally exhausted ventilation, must be used when handling these substances. This includes during transfers or manipulations of small amounts which may generate aerosols and during the weighing of solids if they are toxic.

Storage/Handling
• Store oxidizers away from organic, flammable, dehydrating, or reducing agents.
• Do not store oxidizers in wooden cabinets or on wooden shelves.
• Do not store liquids above eye level (~5 feet).
• Provide secondary containment for strong oxidizing acids such as perchloric and chromic acid.
• Do not use corks or rubber stoppers.

Waste Disposal

Oxidizers must be collected as hazardous waste. Items which have come into contact with these compounds, such as weigh boats, pipettes, and gloves, but which only have trace amounts on them, can be disposed of in the normal trash.

Emergency Procedures

Fire Extinguishers
Fires involving oxidizers are difficult to extinguish. An ABC dry chemical extinguishers can be used in a very small fire, however it may not be effective in a larger fire.

Eyewash/Safety Showers
An ANSI approved eyewash station that can provide quick drenching or flushing of the eyes must be immediately available within 10 seconds travel time for emergency use. An ANSI approved safety drench shower must also be available within 10 seconds travel time from where these compounds are used. Ensure the locations of the eyewashes and safety showers, and how to activate them, are known prior to an emergency.

First Aid Procedures

If inhaled
Remove to fresh air. Follow up with Acute Care or Employee Health as appropriate (203-432-0123).

In case of skin contact
Go to the nearest emergency shower if contaminated. Yell for assistance and rinse for 15 minutes, removing all articles of clothing to ensure contaminate is completely removed. Follow up at Acute Care/Employee Health as appropriate (203-432-0123).

In case of eye contact
Go to the nearest emergency eyewash. Yell for assistance and rinse for 15 minutes. Follow up at Acute Care/Employee Health (203-432-0123).

Spills

Small Spill
If a small spill occurs inside a fume hood or near other local exhaust ventilation, lab personnel should be able to safely clean it up by following these spill clean up procedures:

*Spill control materials for oxidizers are designed to be inert and will not react with the reagent (i.e., vermiculite)*. Never use paper towels or other combustible materials. The waste materials generated during spill cleanup may pose a fire risk and should not remain in the laboratory overnight unless they are stored in an appropriate container.

• Alert people in immediate area of spill
- Increase ventilation in area of spill (open fume hood sashes)
- Wear personal protective equipment, including utility grade nitrile or neoprene gloves
- Confine spill to small area with appropriate inert adsorbent material (i.e., speedy dry) or neutralizing agent if chemical is a corrosive
- Collect residue, place in container, label container, and dispose of as hazardous waste
- Clean spill area with soap and water

**Larger Spill**

- Call EHS for emergency assistance (203-785-3555)
- Evacuate the spill area
- Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering
- Stay nearby until emergency personnel arrive and provide them with information on the chemicals involved

Please list the compounds used by this research group which are covered by this procedure. The list should also include the building/room where they are used.

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**Lab Specific Protocol/Procedure:**

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Principal Investigator’s Signature/Date
Standard Operating Procedure

ORGANIC PEROXIDES AND PEROXIDE FORMING COMPOUNDS*

This standard operating procedure (SOP) is intended to provide general guidance on how to safely work with organic peroxides and peroxide forming compounds. This SOP is generic in nature and only addresses safety issues specific to these materials. In some instances, several general use SOPs may be applicable for a specific chemical.

Organic peroxides are a special class of compounds that have unusual stability problems, making them among the most hazardous substances normally handled in laboratories. In addition, certain laboratory chemicals can react with the oxygen in air to form peroxides. Some may continue to build peroxides to potentially dangerous levels, while others accumulate a relatively low equilibrium concentration of peroxides, which becomes dangerous only after being concentrated by evaporation or distillation. The peroxide becomes concentrated because it is less volatile than the parent chemical. Stabilizers or inhibitors are sometimes added to the liquid to extend its storage life, but distillation will remove the inhibitor.

Examples of organic peroxides and peroxide forming compounds include:

Organic peroxides:
- Benzoyl peroxide
- Butyl Peroxydicarbonate
- Cyclohexanone Peroxide
- Methyl Ethyl Ketone Peroxide
- Methyl Isobutyl Ketone Peroxide

Peroxide formers:

<table>
<thead>
<tr>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemicals which may form explosive peroxides without concentration.</strong></td>
<td><strong>Chemicals which may form peroxides upon concentration (distillation/evaporation).</strong></td>
<td><strong>Chemicals that may autopolymerize as a result of peroxide accumulation.</strong></td>
</tr>
<tr>
<td><strong>Discard within 3 months after opening.</strong></td>
<td><strong>Discard within 12 months after opening.</strong></td>
<td><strong>Discard within 12 months after opening.</strong></td>
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<td>Isopropyl ether</td>
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<tr>
<td>Divinyl acetylene</td>
<td>Diethylene glycol dimethyl ether (diglyme)</td>
<td>Vinyl acetylene</td>
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</table>
### Potential Hazards/Toxicity

As a class, organic peroxides are low powered explosives, however they are particularly hazardous because they are sensitive to heat, friction, impact, light, and other forms of accidental ignition, as well as to strong oxidizing and reducing agents. The unusual stability problems of this class of compounds make them a serious fire and explosion hazard. This class of compounds is also highly flammable.

In addition to the physical hazards, these compounds may also pose health hazards. They are irritating to eyes, skin and respiratory tract and their vapors may cause drowsiness and dizziness. Repeated skin exposures may cause dryness or cracking.

As the hazards may vary by compound, users must familiarize themselves with the specific hazards of the compounds they are working with, which can be found on the chemical’s Safety Data Sheet (SDS). SDSs are available through the ChemWatch link on Yale’s EHS webpage (ehs.yale.edu).

### Personal Protective Equipment (PPE)

*The University’s Personal Protective Equipment Policy can be found here: [http://ehs.yale.edu/PPEPolicy](http://ehs.yale.edu/PPEPolicy)*

#### Eye Protection

Safety glasses must be worn whenever handling organic peroxides or peroxide forming compounds. When there is the potential for splashes, goggles and/or a faceshield must be worn.

#### Hand Protection

Gloves must be worn when handling organic peroxides or peroxide forming compounds. Exam style nitrile gloves (minimum 4mil thickness) are generally adequate for handling these compounds in laboratory settings when skin contact is unlikely. However, if skin contact is likely or larger amounts are being used, then a utility grade glove should be worn over the exam style nitrile. To ensure that the appropriate utility grade glove is selected, use one of the glove selection guides below or contact EHS.


#### Skin and Body Protection

Long pants or clothing that covers the body to the ankles and closed-toe solid top shoes must be worn when handling these compounds. Lab coats must be worn. For organic peroxides or peroxide forming compounds that pose health hazards through dermal absorption, additional protective clothing (i.e., apron, oversleeves) may be appropriate where chemical contact with the skin is likely.

### Engineering Controls

**Fume Hood**

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<table>
<thead>
<tr>
<th>Vinylidene chloride</th>
<th>Diethyl ether</th>
<th>Vinyl chloride</th>
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<td></td>
<td>Dioxane (p-dioxane)</td>
<td>Vinyl pyridine</td>
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<td>Furan</td>
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<td>Vinyl ethers</td>
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</tbody>
</table>
Fume hoods, or other locally exhausted ventilation, must be used whenever handling organic peroxides or peroxide forming compounds.

Storage/Handling

- Avoid friction, grinding, and all forms of impact near peroxides, especially solid peroxides. Do not use glass containers with screw caps or glass stoppers. Polyethylene containers with screw tops may be used.
- Store peroxides at the lowest possible temperature consistent with their solubility or freezing point to minimize the rate of decomposition. Do not store them at or lower than the temperature at which the peroxide freezes or precipitates because peroxides in these forms are extremely sensitive to shock and heat.
- Store all peroxidizable compounds in tightly closed, air-impermeable, light-resistant containers, away from light, heat, direct sunlight, sources of ignition, oxidizers, and oxidizing agents. Storage under nitrogen may be advisable in some cases.
- Do not use metal spatulas to handle peroxides because metal contamination can lead to explosive decomposition. Magnetic stirring bars can unintentionally introduce iron, which can initiate an explosive reaction of peroxides. Teflon, ceramic or wooden spatulas and stirring blades may be used if it is known that the material is not shock sensitive.
- Do not allow these compounds to evaporate to near dryness unless absence of peroxides has been shown.
- Purchase peroxide formers with inhibitors added by the manufacturer when possible.
- For peroxide forming compounds, mark the receipt and opening date on the container and discard within the time frame listed in the table above (or by the manufacturer’s expiration date, if listed on the container).
- If a peroxide-forming chemical or container is of unknown age or history, if crystals or solid masses are visibly present on or in the container or lid, or if the chemical shows discoloration, string-like formations, or liquid stratification, do not open the container. Contact EHS for assistance.

Waste Disposal
Organic peroxides or peroxide forming compounds must be collected as hazardous waste.

Emergency Procedures

Fire Extinguishers
An ABC dry powder extinguisher is appropriate if there is a fire involving these compounds.

Eyewash/Safety Showers
An ANSI approved eyewash station that can provide quick drenching or flushing of the eyes must be immediately available within 10 seconds travel time for emergency use. An ANSI approved safety drench shower must also be available within 10 seconds travel time from where these compounds are used. Ensure the locations of the eyewashes and safety showers, and how to activate them, are known prior to an emergency.

First Aid Procedures

If inhaled
Remove to fresh air. Follow up with Acute Care or Employee Health as appropriate (203-432-0123).

In case of skin contact
Go to the nearest emergency shower if contaminated. Yell for assistance and rinse for 15 minutes, removing all articles of clothing to ensure contaminate is completely removed. Follow up at Acute Care/Employee Health as appropriate (203-432-0123).

In case of eye contact
Go to the nearest emergency eyewash. Yell for assistance and rinse for 15 minutes. Follow up at Acute Care/Employee Health (203-432-0123).

Spills
Small Spill
If a small spill occurs, lab personnel should be able to safely clean it up by following these spill clean up procedures:

- Alert people in immediate area of spill
- Increase ventilation in area of spill (open fume hood sashes)
- Wear personal protective equipment, including utility grade gloves
- Confine/adsorb spill of liquids with spill clean up pads or absorbent
- Keep spills of solid peroxides wet with an appropriate inert solvent (e.g. water or aliphatic hydrocarbon). Cover the spill with a wet (water) mixture (1:1:1, by weight) of sodium carbonate, vermiculite, and sand.
- Collect residue, place in container, label container, and dispose of as hazardous waste
- Clean spill area with soap and water

Larger Spill
- Call EHS for emergency assistance (203-785-3555)
- Evacuate the spill area
- Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering
- Stay nearby until emergency personnel arrive and provide them with information on the chemicals involved

Please list the compounds used by this research group which are covered by this procedure. The list should also include the building/room where they are used.

Lab Specific Protocol/Procedure:

Principal Investigator’s Signature/Date
## APPENDIX O  CHEMICALS THAT MAY FORM EXPLOSIVE PEROXIDES

(This list is not all inclusive)

<table>
<thead>
<tr>
<th>Class A</th>
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APPENDIX P       TOXIC AND FLAMMABLE GASES REQUIRING EHS APPROVAL

(This list is not all inclusive)

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<tbody>
<tr>
<td>Ammonia</td>
<td>Fluorine</td>
<td>Nitrogen trioxide</td>
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<td>Arsenic pentafluoride</td>
<td>Germane</td>
<td>Nitrosyl chloride</td>
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<td>Iodine pentafluoride</td>
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<td>Nickel carbonyl</td>
<td>Trifluorochloroethylene</td>
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<td>Dichlorosilane</td>
<td>Nitric oxide</td>
<td>Tungsten hexafluoride</td>
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<tr>
<td>Dinitrogen tetroxide</td>
<td>Nitrogen dioxide</td>
<td>Vinyl chloride</td>
</tr>
</tbody>
</table>
Standard Operating Procedure

CORROSIVES

This standard operating procedure (SOP) is intended to provide general guidance on how to safely work with corrosive materials. This SOP is generic in nature and only addresses safety issues specific to corrosive chemicals. In some instances, several general use SOPs may be applicable for a specific chemical.

The major classes of corrosive chemicals are strong acids and bases, dehydrating agents, and oxidizing agents. Liquid corrosive chemicals are those with a pH of 4.0 or lower or a pH of 9 or higher. Solid chemicals are considered corrosive if when in solution they fall in the above pH range. A highly corrosive chemical has a pH of 2 or lower or a pH of 12.5 or higher. OSHA defines a material as corrosive if it meets either of these criteria:

- **Corrosive to skin**: a substance which produces irreversible damage to the skin following an application of the substance for up to 4 hours.
- **Corrosive to metal**: a substance or a mixture that by chemical action will materially damage, or even destroy, metals.

**Examples of common corrosives include:**

- **Strong acids**:
  - Hydrochloric acid
  - Nitric acid
  - Phosphoric acid
- **Strong bases**:
  - Sodium hydroxide
  - Potassium hydroxide
  - Ammonia hydroxide
- **Strong dehydrating agents**:
  - Phosphorus pentoxide
  - Calcium oxide
  - Sulfuric acid
- **Strong oxidizing agents**:
  - Hydrogen peroxide (≥30%)
  - Sodium hypochlorite
- **Corrosive solids**:
  - Phenol
  - Phosphorous
- **Corrosive gases**:
  - Chlorine
  - Ammonia

This SOP does not apply to hydrofluoric acid, perchloric acid, picric acid, aqua regia, or piranha solution.

**Potential Hazards/Toxicity**
Corrosives materials can cause visible destruction to human tissue, and/or irreversible damage, at the site of contact. These chemicals can erode the skin and the respiratory epithelium and are particularly damaging to the eyes. Inhalation of vapors or mists of these substances can cause severe bronchial irritation.

Most acids are liquids and most bases are solids. Acids, especially when concentrated, are most likely to cause immediate pain when they come in contact with the body. Contact with strong bases usually does not cause immediate pain. This allows the base time to react with the body part and a serious injury may result.

Corrosive compounds present a physical hazard as well. When they come into contact with some metals, like aluminum, they may react and generate hydrogen gas.

As the hazards may vary by compound, users must familiarize themselves with the specific hazards of the compounds they are working with, which can be found on the chemical's Safety Data Sheet (SDS). SDSs are available through the ChemWatch link on Yale’s EHS webpage (ehs.yale.edu).

**Personal Protective Equipment (PPE)**
*The University’s Personal Protective Equipment Policy can be found here: [http://ehs.yale.edu/PPEPolicy](http://ehs.yale.edu/PPEPolicy)*

**Eye Protection**
Safety glasses or chemical goggles must be worn whenever handling corrosive chemicals. If there is a potential for splash to the face, then a faceshield must be worn over tight fitting goggles.

**Hand Protection**
Gloves must be worn when handling corrosive chemicals. Exam style nitrile gloves (minimum 4mil thickness) should be adequate for handling small quantities of most of these in general laboratory settings. However, if skin contact is likely or larger amounts are being used, then a utility grade nitrile or neoprene glove should be worn over the exam style nitrile.

**Skin and Body Protection**
Long pants or clothing that covers the body to the ankles and closed-toe solid top shoes must be worn when handling these compounds. Lab coats must be worn. Additional protective clothing (i.e., chemical resistant apron) may be necessary when using larger amounts and/or a potential for a splash to the body exists.

**Engineering Controls**
Fume hoods, or other locally exhausted ventilation, must be used when handling corrosive compounds.

**Storage/Handling**
Store liquids and solids separately. Store away from incompatibles; many corrosive materials are incompatible with each other, i.e., oxidizing acids are incompatible with organic acids, and acids are incompatible with bases.

- **Liquids:**
  - Transport in secondary containment.
  - Whenever possible, purchase corrosive liquids in safety coated bottles.
  - Keep concentrated corrosive compounds in secondary containment.
  - Store in approved locations, such as chemical cabinets. Strong acids will corrode most metal cabinets. Non-metallic or epoxy painted cabinets should be used.
  - Do not store above eye level (~5 feet) or on benches.
  - Always add acid to water, never water to acid.
Avoid violent reactions. Dilution of mineral acid with water is highly exothermic and vessels may become hot enough to burn skin on touch, cause sudden boil over, or to violently de-gas.

- **Corrosive Gases:**
  - Use and store in vented cabinets or inside a fume hood.
  - To prevent releases to the environment, or possible equipment damage, it may be necessary to scrub exhaust from processes which utilize large amounts of corrosive gases even when working in the fume hood.
  - Close regulators and valves when the cylinder is not in use and flush with dry air or nitrogen after use.

**Waste Disposal**
Corrosive compounds which have a pH of 5.5-9.5 and do not exhibit any other hazard (i.e., toxicity) may be disposed of down the drain. All other corrosive waste must be collected as hazardous waste.

**Emergency Procedures**

**Fire Extinguishers**
An ABC dry powder extinguisher is appropriate if there is a fire involving corrosive compounds.

**Eyewash/Safety Showers**
An ANSI approved eyewash station that can provide quick drenching or flushing of the eyes must be immediately available within 10 seconds travel time for emergency use. An ANSI approved safety drench shower must also be available within 10 seconds travel time from where these compounds are used. Ensure the locations of the eyewashes and safety showers, and how to activate them, are known prior to an emergency.

**First Aid Procedures**

**If inhaled**
Remove to fresh air. Follow up with Acute Care or Employee Health as appropriate (203-432-0123).

**In case of skin contact**
Go to the nearest emergency shower if contaminated. Yell for assistance and rinse for 15 minutes, removing all articles of clothing to ensure contaminant is completely removed. Follow up at Acute Care/Employee Health as appropriate (203-432-0123).

**In case of eye contact**
Go to the nearest emergency eyewash. Yell for assistance and rinse for 15 minutes. Follow up at Acute Care/Employee Health (203-432-0123).

**Spills**

**Small Spill**
If a small spill occurs inside a fume hood or near other local exhaust ventilation, lab personnel should be able to safely clean it up by following standard spill clean up procedures:

- Alert people in immediate area of spill
- Increase ventilation in area of spill (open fume hood sashes)
- Wear personal protective equipment, including utility grade nitrile gloves
- If available, cover spill with acid/base neutralizer
- If neutralizer is not available, confine spill to small area with adsorbent material (pads, vermiculite)
- Collect residue, place in container, label container, and dispose of as hazardous waste
- Clean spill area with soap and water

**Larger Spill**

- Call EHS for emergency assistance (203-785-3555)
- Evacuate the spill area
- Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering
- Stay nearby until emergency personnel arrive and provide them with information on the chemicals involved

**Please list the compounds used by this research group which are covered by this procedure. The list should also include the building/room where they are used.**

<p>| |</p>
<table>
<thead>
<tr>
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**Lab Specific Protocol/Procedure:**

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______________________________
Principal Investigator’s Signature/Date
Standard Operating Procedure

CARCINOGENS

This standard operating procedure (SOP) is intended to provide general guidance on how to safely work with carcinogenic materials. This SOP is generic in nature and only addresses safety issues specific to carcinogens. In some instances, several general use SOPs may be applicable for a specific chemical. In addition, SOPs exist for some carcinogens; those chemicals are denoted with an asterisk (*) in the list below.

A chemical is considered a carcinogen if identified as such by any of the following:

- National Toxicology Program, Annual Report on Carcinogens (latest edition) – listed under the category of “known to be carcinogens”
- International Agency for Research on Cancer, Monographs (latest edition) – listed as Group 1
- International Agency for Research on Cancer, Monographs (latest edition) – Group 2A or Group 2B reasonably anticipated to be carcinogens* by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:
  - 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/m3;
  - After repeated skin application of less than 300 mg/kg of body weight per week; or
  - After oral dosages of less than 50 mg/kg of body weight per day.
- Regulated by OSHA as a carcinogen under 29 CFR 1910 Subpart Z, Toxic and Hazardous Substances
- GHS Category 1 “Known or Presumed Carcinogen” (includes Category 1A & 1B)

Examples of known human carcinogens include:

- Arsenic/Inorganic arsenic compounds
- Asbestos
- Benzene
- Beryllium/Beryllium compounds
- Bis(chloromethyl) Ether
- Cadmium/Cadmium compounds
- Ethylene Oxide*
- Formaldehyde*
- Vinyl Chloride

Potential Hazards/Toxicity
Carcinogenic compounds can initiate or increase the proliferation of malignant neoplastic cells or the development of malignant or potentially malignant tumors. They are chronic toxins with long latency periods that can cause damage after repeated or long duration exposures and often do not have immediate apparent harmful effects. Users can be exposed to these compounds through inhalation, ingestion, and/or dermal absorption. Dermal absorption may cause the same toxic effects as inhalation or ingestion.

Users must familiarize themselves with the specific hazards of the compounds they are working with, which can be found on the chemical's Safety Data Sheet (SDS). SDSs are available through the ChemWatch link on Yale’s EHS webpage (ehs.yale.edu).
Personal Protective Equipment (PPE)
The University’s Personal Protective Equipment Policy can be found here: http://ehs.yale.edu/PPEPolicy

Eye Protection
Safety glasses must be worn whenever handling carcinogenic chemicals. When there is the potential for splashes, goggles must be worn.

Hand Protection
Gloves must be worn when handling carcinogenic chemicals. Exam style nitrile gloves (minimum 4mil thickness) should be adequate for handling small quantities of most of these in general laboratory settings. However, if skin contact is likely or large amounts are being used, then a utility grade glove should be worn over the exam style nitrile. To ensure that the appropriate utility grade glove is selected, use one of the glove selection guides below or contact EHS.


Skin and Body Protection
Long pants or clothing that covers the body to the ankles and closed-toe solid top shoes must be worn when these compounds. Lab coats must be worn. If skin contact is likely, then additional protective clothing (i.e., apron, oversleeves) is required.

Engineering Controls

Fume Hood
Fume hoods, or other locally exhausted ventilation, must be used when handling these substances. This includes during transfers or manipulations of small amounts which may generate aerosols (i.e., pipetting) and during the weighing of solids.

Storage/Handling

• Demarcate an area where work may be conducted with carcinogens. A designated area may be an entire laboratory, a defined area within the laboratory, or a device such as a laboratory hood. Designated areas must be clearly marked with signs that identify the chemical hazard and include an appropriate warning; for example: WARNING! BENZENE WORK AREA – CARCINOGEN. The carcinogen pictogram on the laboratory door sign also identifies the laboratory as a designated area.
  o Upon leaving the designated area, remove any personal protective equipment worn and wash hands with soap and water.
  o After each use (or day), wipe down the immediate work area and equipment to prevent accumulation of chemical residue.
  o At the end of each project, thoroughly decontaminate the designated area before resuming normal laboratory work in the area.

• Store in approved locations, such as chemical cabinets. Carcinogens which are also flammable should be stored in flammable rated cabinets. Do not store liquids above eye level (~5 feet) or on benches.

• Keep segregated from incompatible chemicals.

Waste Disposal
Carcinogens must be collected as hazardous waste. Items which have come into contact with the carcinogens, such as weigh boats, kimwipes, pipettes, and gloves, but which only have trace amounts on them, can be disposed of in the normal trash. This does not include items contaminated with carcinogens.
which are P listed/acutely toxic, i.e., arsenic compounds. All items contaminated with acutely toxic compounds must be collected as hazardous waste.

**Emergency Procedures**

**Fire Extinguishers**
Both ABC dry powder and carbon dioxide extinguishers are appropriate for most fires involving carcinogens.

**Eyewash/Safety Showers**
An ANSI approved eyewash station that can provide quick drenching or flushing of the eyes must be immediately available within 10 seconds travel time for emergency use. An ANSI approved safety drench shower must also be available within 10 seconds travel time from where these compounds are used. Ensure the locations of the eyewashes and safety showers, and how to activate them, are known prior to an emergency.

**First Aid Procedures**

**If inhaled**
Remove to fresh air. Follow up with Acute Care or Employee Health as appropriate (203-432-0123).

**In case of skin contact**
Go to the nearest emergency shower if contaminated. Yell for assistance and rinse for 15 minutes, removing all articles of clothing to ensure contaminant is completely removed. Follow up at Acute Care/Employee Health as appropriate (203-432-0123).

**In case of eye contact**
Go to the nearest emergency eyewash. Yell for assistance and rinse for 15 minutes. Follow up at Acute Care/Employee Health (203-432-0123).

**Spills**

**Small Spill**
If a small spill occurs inside a fume hood or near other local exhaust ventilation, lab personnel should be able to safely clean it up by following standard spill clean up procedures:

- Alert people in immediate area of spill
- Increase ventilation in area of spill (open fume hood sashes)
- Wear personal protective equipment, including utility grade gloves
- Confine spill to small area with adsorbent material (pads, vermiculite)
- Collect residue, place in container, label container, and dispose of as hazardous waste
- Clean spill area with soap and water

**Larger Spill**

- Call EHS for emergency assistance (203-785-3555)
- Evacuate the spill area
- Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering
- Stay nearby until emergency personnel arrive and provide them with information on the chemicals involved
Please list the compounds used by this research group which are covered by this procedure. The list should also include the building/room where they are used.

Lab Specific Protocol/Procedure:

Principal Investigator’s Signature/Date
This standard operating procedure (SOP) is intended to provide general guidance on how to safely work with acutely toxic materials. This SOP is generic in nature and only addresses safety issues specific to acutely toxic chemicals. In some instances, several general use SOPs may be applicable for a specific chemical. In addition, SOPs exist for some of the more common acutely toxic chemicals used on campus; those chemicals are denoted with an asterisk (*) in the list below.

A chemical is considered to be acutely toxic when it falls within any of the following categories:

- A chemical with a median lethal dose (LD50) of 50 mg or less per kg of body weight when administered orally to albino rats weighing between 200 and 300 gm each
- A chemical with a median lethal dose (LD50) of 200 mg or less per kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 Kg each
- A chemical that has a median lethal concentration (LC50) in air of 500 ppm by volume or less of gas, 2.0 mg per liter for vapor, or 0.5 mg per liter or less of dust and mists, when administered by continuous inhalation for 4 hours.

Examples of acutely toxic chemicals include:

- Acrolein*
- Bromine
- Cyanide salts (potassium and sodium)*
- Hydrogen cyanide
- Nickel carbonyl
- Organolead compounds
- Organomercury compounds
- Organotin compounds
- Osmium tetroxide
- Pentaborane
- Phosgene

Potential Hazards/Toxicity
Substances that possess the characteristic of high acute toxicity can cause damage after a single or short-term exposure, the health effects of which can range from illness to even death. Many of these compounds must not be handled while working alone (i.e., cyanides, organic metals, phosgene).

As the hazards may vary by compound, users must familiarize themselves with the specific hazards of the compounds they are working with, which can be found on the chemical’s Safety Data Sheet (SDS). SDSs are available through the ChemWatch link on Yale’s EHS webpage (ehs.yale.edu).

Personal Protective Equipment (PPE)
The University’s Personal Protective Equipment Policy can be found here: [http://ehs.yale.edu/PPEPolicy](http://ehs.yale.edu/PPEPolicy)
Eye Protection
Safety glasses must be worn whenever handling acutely toxic chemicals. When there is the potential for splashes, goggles and/or a faceshield must be worn.

Hand Protection
Gloves must be worn when handling acutely toxic chemicals. It is possible that double exam style nitrile gloves (minimum 4mil thickness) may be adequate for handling very small quantities of some of these compounds in general laboratory settings when skin contact is unlikely; however, in many cases a utility grade glove must be worn over the exam style nitrile. To ensure that the appropriate utility grade glove is selected, use one of the glove selection guides below or contact EHS.


http://www.northsafety.com/ClientFormImages/NorthSafety/CorpSite/E8D15F2E-1F59-454F-B8F0-147FA2B9D81D.pdf

Skin and Body Protection
Long pants or clothing that covers the body to the ankles and closed-toe solid top shoes must be worn when these compounds. Lab coats must be worn. For compounds that are toxic through dermal absorption, additional protective clothing (i.e., apron, oversleeves) is appropriate where chemical contact with the skin is likely.

Engineering Controls
Fume Hood
Fume hoods, or other locally exhausted ventilation, must be used when handling these substances. This includes during transfers or manipulations of small amounts which may generate aerosols and during the weighing of solids.

Storage/Handling

- Demarcate an area where work may be conducted with acutely toxic chemicals. A designated area may be an entire laboratory, a defined area within the laboratory, or a device such as a laboratory hood. Designated areas must be clearly marked with signs that identify the chemical hazard and include an appropriate warning; for example: WARNING! SODIUM CYANIDE WORK AREA – HIGHLY TOXIC. The acutely toxic pictogram on the laboratory door sign also identifies the laboratory as a designated area.
  - Upon leaving the designated area, remove any personal protective equipment worn and wash hands with soap and water.
  - After each use (or day), wipe down the immediate work area and equipment to prevent accumulation of chemical residue. Decontamination procedures vary depending on the material being handled. The toxicity of some materials can be neutralized with other reagents.
  - At the end of each project, thoroughly decontaminate the designated area before resuming normal laboratory work in the area.
- Vacuum pumps used in procedures should be protected from contamination by installing two collection flasks in series along with an in-line hydroscopic filter.
- Analytical instruments or other laboratory equipment generating vapors and/or aerosols during their operation must be locally exhausted or vented in a fume hood.
- Store chemicals which are acutely toxic by inhalation in vented/exhausted chemical cabinets.
- Store acutely toxic liquids at/below eye level (~5 feet).
- Keep segregated from incompatible chemicals.

Waste Disposal
All acutely toxic solutions/stock materials must be collected as hazardous waste. All items contaminated with acutely toxic (P-Listed) compounds must be collected as hazardous waste. This includes empty reagent bottles, weigh boats, pipette tips, kimwipes, and other similar items that have come into contact with these compounds.

Emergency Procedures

Fire Extinguishers
Both ABC dry powder and carbon dioxide extinguishers are appropriate for most fires involving acutely toxic compounds.

Eyewash/Safety Showers
An ANSI approved eyewash station that can provide quick drenching or flushing of the eyes must be immediately available within 10 seconds travel time for emergency use. An ANSI approved safety drench shower must also be available within 10 seconds travel time from where these compounds are used. Ensure the locations of the eyewashes and safety showers, and how to activate them, are known prior to an emergency.

First Aid Procedures
If inhaled
Remove to fresh air. Call 911 for immediate medical attention.

In case of skin contact
Go to the nearest emergency shower if contaminated. Yell for assistance and rinse for 15 minutes, removing all articles of clothing to ensure contaminate is completely removed. Call 911 for immediate medical attention.

In case of eye contact
Go to the nearest emergency eyewash. Yell for assistance and rinse for 15 minutes. Call 911 for immediate medical attention.

Spills
Small Spill (inside a fume hood)
If a small spill occurs inside a fume hood, lab personnel should be able to safely clean it up by following standard spill clean up procedures:

- Alert people in immediate area of spill
- Wear personal protective equipment, including utility grade gloves
- Confine spill to small area with adsorbent material (pads, vermiculite)
- Collect residue, place in container, label container, and dispose of as hazardous waste
- Clean spill area with soap and water

Larger Spill/Any spill outside a fume hood

- Call EHS for emergency assistance (203-785-3555)
- Evacuate the spill area
- Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering
- Stay nearby until emergency personnel arrive and provide them with information on the chemicals involved
Please list the compounds used by this research group which are covered by this procedure. The list should also include the building/room where they are used.

Lab Specific Protocol/Procedure:

Principal Investigator’s Signature/Date
## APPENDIX T

**HIGHLY TOXIC LIQUIDS AND SOLIDS REQUIRING EHS REVIEW AND APPROVAL**

(This list is not all inclusive)

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<tr>
<th>Chemical</th>
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<tbody>
<tr>
<td>1,1-Dimethylethylenimine</td>
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<td>1,2-Dimethylhydrazine</td>
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<td>1,4-Dinitrosopiperazine</td>
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<td>bromine</td>
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<td>diazomethane</td>
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<tr>
<td>Hydrofluoric acid (Hydrogen fluoride)</td>
<td>7664-39-3</td>
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<tr>
<td>lead - organic</td>
<td>varies</td>
</tr>
<tr>
<td>mercury - organic</td>
<td>varies</td>
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<td>Mercury – metallic</td>
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<td>Methylhydrazine</td>
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<td>MPTP (1-Methyl-4-phenyl-1,2,3,6-tetrahydropyridine hydrochloride)</td>
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<td>osmium tetroxide</td>
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<td>potassium cyanide</td>
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<td>sodium cyanide</td>
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<td>Thionyl chloride</td>
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<td>Bromoethyl methanesulfonate</td>
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### APPENDIX U  CARCINOGENS AND REPRODUCTIVE TOXINS REQUIRING EHS REVIEW AND APPROVAL

(This list is not all inclusive)

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<th>Chemical</th>
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<td>1,2-Dibromo-3-chloropropene</td>
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<td>1,2-dichloroethane</td>
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<tr>
<td>1,3-butanediene</td>
<td>106-99-0</td>
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<td>1,3-Propane sultone</td>
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<td>1,4-dioxane (p-dioxane)</td>
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<td>2-nitropropane</td>
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<td>3-Methylcholanthrene</td>
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<td>3,3'-Dichlorobenzidine (&amp; its salts)</td>
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## APPENDIX V
### DEPARTMENT OF HOMELAND SECURITY (DHS) REGULATED CHEMICALS

**Solids and Liquids**

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<th>DHS listed Chemical</th>
<th>CAS #</th>
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<td>1,4-Bis(2-chloroethylthio)-n-butane</td>
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<td>Nitromannite (Mannitol hexanitrate)</td>
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<td>Ammonium nitrate, [with &gt;0.2 percent combustible substances, including any organic substance calculated as carbon, to the exclusion of any other added substance]</td>
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<td>Nitrostarch</td>
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