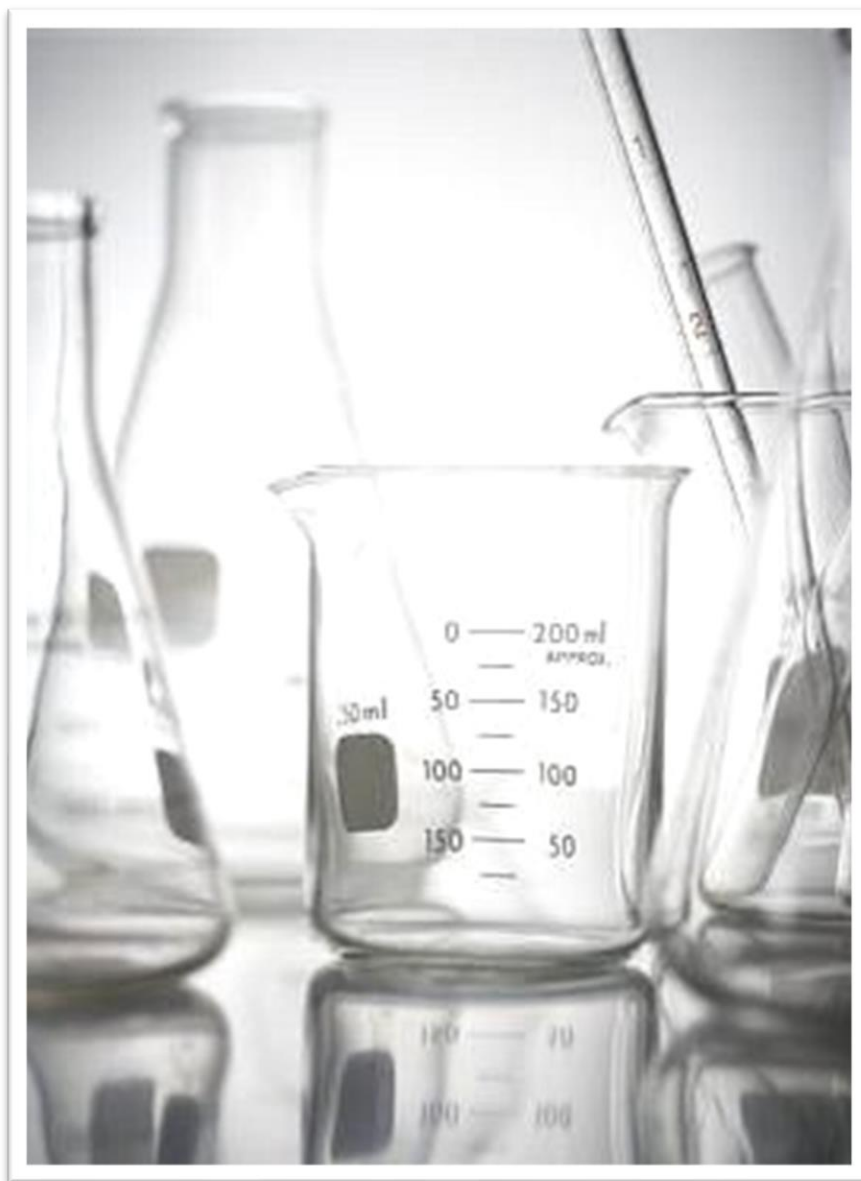


Laboratory Chemical Hygiene Plan



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SECTION 1.0 YALE UNIVERSITY LABORATORY CHEMICAL HYGIENE PLAN

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 maintained by the laboratory and available for review.

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. Printed copies can be made available by contacting Yale Environmental Health and Safety (203-785-3550).

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. They are 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 personnel, who is responsible for:

- Being aware of the hazards of the materials they are 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, Yale Environmental Health & Safety, 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), clinical pathology labs, and conservation labs for art galleries, museums, and libraries, are not laboratories covered under this plan.*

1.3.2 Hazardous Chemical Definition

The OSHA Laboratory 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
- asphyxiants
- 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's hazard communication standard was updated in 2012 and requires chemical labels and safety data sheets to be uniform and consistent with global regulations. Products manufactured beginning June 2015 were required to be labeled in compliance with this regulation. There are 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 June 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 the sample form in Appendix D. 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. This training, entitled Laboratory Chemical Safety, is available online at ehs.yale.edu. Principal Investigators are responsible for the safety in their laboratories and must also receive this information and complete this training. Classroom training sessions can also be arranged by contacting Yale Environmental Health and Safety. Additional laboratory specific safety training is provided by the Principal Investigator or supervisor.

All 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 the researcher 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*” available online at ehs.yale.edu. 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 available online as well as 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 a MSDSonline, a safety data sheet management system. Vendor-specific Safety Data Sheets can be easily obtained through this system, which is accessible from any Yale IP address through the Yale EHS website at ehs.yale.edu.

Yale Environmental Health and Safety also maintains a library of reference materials addressing chemical health and safety issues. In addition, EHS 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 June 2015 are required to contain the information mandated in the 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 allows 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 ensure 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) 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 were 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.

Safety Data Sheets can be easily obtained through MSDSonline, an SDS database management system. This system is accessible through the Yale EHS website at ehs.yale.edu when on the Yale network.

If you do not have web access and want to review a hard copy 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 were required to provide Safety Data Sheets that conform to the strict requirements of the updated hazard communication standard. This updated 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; ACGHI 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:

- Laboratory safety information postings 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 phone numbers of the Principal Investigator and other responsible laboratory personnel. These postings 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, fume hoods, etc, as appropriate.
- Warnings near areas or equipment where special or unusual hazards exist.

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 or other local exhaust ventilation. 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/local exhaust ventilation or used in larger than lab-scale quantities. During annual laboratory safety inspections, Safety Advisors from Yale Environmental Health and Safety (EHS) will identify these situations during their regular inspections and Industrial Hygienists from Yale EHS will perform follow-up exposure assessments as necessary.

The EHS 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 Employee 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. Information on reproductive and developmental hazards, including lists of those materials suspected of causing such effects, can be found in the “*Reproductive and Developmental Hazards Safety Guidelines*” at ehs.yale.edu.

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 electronic 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 issue noted on the report. 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. These circumstances include a) those chemicals placed on the restricted chemicals list due to the hazardous nature of the chemical, b) hazardous chemicals or operations that the laboratory are not familiar with and need special guidance, and c) hazardous chemicals that are used in a manner outside of the procedures outlined in Section 3 of this Chemical Hygiene Plan, including larger volumes and scaling up of experiments.

The chemicals which are included on the restricted list due to their hazardous nature (condition “a” above) are divided into two tiers. Tier 1 chemicals cannot be purchased until a completed chemical registration is submitted using EHS Integrator (ehs.yale.edu). As part of this registration process, the researcher must provide detailed information on the research protocol, including information on the specific chemical(s), proposed handling, storage, and disposal information. Once the researcher submits the registration, it is routed to EHS and the Principal Investigator for review and approval. Tier 2 chemicals may not present the same level of hazard as Tier 1 chemicals and therefore do not require registration. Researchers who handle these types of materials are provided with information specific to the hazard presented by the chemical for their review. Chemicals in both Tier 1 and Tier 2 are routed to EHS for review

and approval.

For conditions “b” and “c” above, i.e. hazardous chemicals or operations that the laboratory are not familiar with and need special guidance, or for hazardous chemicals being used in a manner outside of the procedures outlined in this plan, EHS will need to review the proposed activity/procedure and provide approval prior to research beginning. Depending on the procedure and materials, the researcher may be asked to complete the chemical registration using EHS Integrator or submit a protocol, including all relevant safety information, to EHS for review.

1.10 RESPIRATORY PROTECTION PROGRAM

The University works 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. An effective respiratory protection program is essential to ensure that the personnel using such equipment are adequately trained and 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 EHS Safety Advisor.

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 Laboratory Hazard Assessment Tool (LHAT) to determine additional PPE requirements for tasks or activities in the lab. At a minimum, safety glasses, lab coat, exam-style 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.
- Pull back and secure long hair; long beards should also be contained.
- 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 alone while using high hazard chemicals or performing high hazard operations. 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. See the *"Policy on Working Alone in Laboratories"* (ehs.yale.edu) for University-wide standards for working alone in laboratories as well as a list of materials/equipment which are prohibited to be used while working alone.
- Complete required EHS training prior to beginning work. Successful completion of Yale University's Laboratory Chemical 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, toxic, or malodorous 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 directly 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 Operations to repair fume hoods 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, 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 E for sample 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 these steps:

- list materials and methods;

- identify hazards;
- select safety measures;
- prepare for mishaps;
- reassess risk.

See Appendix F for a sample chemical protocol risk assessment form that can assist in conducting a successful risk assessment.

Hazards may exist that are not fully recognized, even when performing familiar tasks. 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 previous 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, contact 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 person'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 exhaust ventilation (e.g., use of fume hoods)

A laboratory coat, chemical resistant gloves, protective eyewear, clothing that covers the legs and closed-toe, solid top shoes are required to be worn in Yale laboratories whenever handling hazardous chemicals. Additional personal protective equipment, such as face shield, utility-grade chemical resistant 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 Laboratory Hazard Assessment Tool (LHAT) 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 for information on how to implement the PPE policy in a laboratory as well as a table outlining the activities and requirements found in the online LHAT.

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 safety glasses or prescription glasses, pants or clothing that covers the legs (shorts and short skirts are not acceptable) and closed-toe, solid top shoes in the laboratory at all times. Safety glasses and a laboratory coat are required to be worn whenever working with hazardous materials. Prescription glasses are only allowed to be worn when working with hazardous materials if they are prescriptions **safety glasses with side shields**. Laboratory coats are intended to prevent contact with dirt, chemical dusts and minor chemical splashes or spills. If a lab coat becomes contaminated, it should be removed immediately and the affected skin surface washed thoroughly.

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 Laboratory Hazard 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 yale.edu

2.3.3 Gloves

Chemical resistant gloves must 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. All laboratories that use chemicals should 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 high 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.

Glove Material	Intended Use	Advantages	Disadvantages
Latex exam style	Incidental Contact	<ul style="list-style-type: none">• Good for biological and water-based materials• User acceptability	<ul style="list-style-type: none">• Poor for organic solvents• Hard to detect puncture holes• Latex allergy issues
Nitrile - exam style	Incidental Contact	<ul style="list-style-type: none">▪ Good for solvents, oils, greases, some acids and bases▪ Clear indication of tears and breaks▪ User acceptability	<ul style="list-style-type: none">• May be slightly more expensive than latex

Nitrile - utility style	Extended Contact	<ul style="list-style-type: none"> ▪ Good for solvents, oils, greases, some acids and bases ▪ Can be washed and reused 	<ul style="list-style-type: none"> • Not effective for halogenated and aromatic hydrocarbons
Neoprene – utility style	Extended contact	<ul style="list-style-type: none"> ▪ Good for acids, bases alcohols, fuels, peroxides, hydrocarbons, and phenols 	<ul style="list-style-type: none"> • Poor for halogenated and aromatic hydrocarbons
Butyl rubber - utility style	Extended contact	<ul style="list-style-type: none"> ▪ Good for ketones and esters 	<ul style="list-style-type: none"> ▪ High cost
Silver Shield - Teflon	Extended contact	<ul style="list-style-type: none"> ▪ Good for most chemicals 	<ul style="list-style-type: none"> ▪ Lack of dexterity ▪ Very expensive

Contact your EHS Safety Advisor 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 or stored. 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 N/P/R95 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 (airline 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 protection 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 Employee Health Physician (EHP). The EHP 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 Employee Health Office 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, respirator fittesting is not required. 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, gases and particles 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. 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.. All fume hoods are tested by EHS on an annual basis to verify that the appropriate face velocity is maintained.

There are a wide variety of fume hood styles and systems on campus including constant volume and variable air volume systems. Some 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.

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 reduced 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 actively working at the hood.

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 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.

- Small amounts of closed working containers may be kept stored in the fume hood. Containers in fume hoods do not need to be in trays.
- Follow the instructions on the “Safe Use of Laboratory Fume Hoods” sticker posted on the hoods.

All work involving volatile, malodorous 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 Filtering Fume Hoods

Filtering fume hoods, or ductless chemical fume hoods, are hoods which recycle air to the laboratory after passing it through a filter. They 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 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 filtering fume hoods is the potential for vapors to not fully be removed by the filtering media and be returned to the laboratory. Many filtering fume hoods do not have a method for detecting when the filters are saturated and breakthrough of organic vapors begins. Those that have monitors may depend on non-specific chemical sensors that will respond at different concentrations for different substances, and some substances will not be detected. These are all reasons why it is critical that these systems not be used without EHS approval..

Applications where these units might be appropriate include the control of particulates, low hazard chemicals, and nuisance odors. **Filtering hoods should not be used to protect laboratory workers from toxicologically significant concentrations of hazardous chemicals.**

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 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. There should be at least 32” inches of clear space around the shower and 6’ of clear space around the eyewash.
- 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 must be easily accessible to the laboratory and include the appropriate fire extinguisher(s) (or fire hoses, fire blankets, and automatic extinguishing systems), as determined by the Yale Office of Fire Code 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 identified as Chemicals of Interest by the Department of Homeland Security (DHS) are flagged for approval by EHS upon purchase and included in a container-level chemical inventory system.

The list of restricted 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 purchases of hazardous liquids from the stockroom if there is no chemical carrier available to bring the containers 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. The requirements in this section apply to chemicals in storage ONLY, not to working containers.

This section details basic guidelines for chemical storage. However, it should be noted that some chemicals may fall into more than one hazard category and the label and Safety Data Sheet should be reviewed for specific storage requirements. Segregation of chemicals may be achieved by adequate distance or by a physical barrier such as a secondary container, tray, or cabinet.

Basic guidelines to chemical storage by compatibility is as follows:

Solids

Most solid chemicals can be stored together, but the following classes of solid hazardous materials should be kept separated. This separation may often be achieved with distance, trays or other secondary containment:

- Flammable solids (ex: phosphorus, magnesium, lithium)
- Water reactives (ex: calcium carbide, magnesium, lithium, potassium, sodium)
- Highly toxic solids (ex: cyanide salts, sulfide salts, osmium tetroxide)

Liquids

- Flammables (ex: acetone, diethyl ether, ethanol, hexanes, methanol, xylene)

- Acids (separate organic acids from oxidizing mineral acids)
 - Oxidizing mineral acids (ex: sulfuric, nitric, chromic, perchloric)
 - Organic acids (ex: acetic, butyric, formic, propionic)
- Bases (ex: ammonium hydroxide, sodium hydroxide, potassium hydroxide)
- Oxidizers (ex: bromine, hydrogen peroxide, oxidizing acids)

Gases

- Flammable gases (ex: hydrogen)
- Oxidizing gases (ex: oxygen)
- Toxic gases (ex: ammonia, carbon monoxide)

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

It is preferable to store flammable chemicals in flammable storage cabinets, if available. Up to 10 gallons of flammable liquids can 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.

Keep flammable liquids away from oxidizing acids, oxidizers, and sources of ignition.

Hazardous chemicals generally should not be stored on bench tops, directly on the floor, or under sinks. Reasonably small amounts of closed containers of chemicals may be kept in the fume hood or on the bench, if necessary. Chemicals that are incompatible with adjacent chemicals should be put in a separate tray. Containers in fume hoods do not need to be in trays.

Closed containers of acids and bases may be stored in the same cabinet if segregated by placing them in trays or other secondary containment.

Corrosive, flammable or toxic liquids should not be stored above eye level (~5 feet).

Avoid exposure of stored chemicals 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.

Ensure 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.

See Section 3.2, Highly Reactive Chemicals and High Energy Oxidizers, for information on handling and storage limitations of these compounds.

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 of peroxide formers should be dated upon receipt and upon opening. For specific information on storage and testing of these compounds, refer to the “*Peroxide Forming Chemicals*” safety guidelines at ehs.yale.edu.

For additional information on chemical stability, contact your supervisor or your EHS Safety Advisor.

2.5 CHEMICAL RELEASES

2.5.1 General Information

Try to anticipate the types of chemical releases that can occur in the laboratory and ensure that all laboratory personnel know the appropriate steps to take if a release were to occur. This includes keeping the necessary equipment (spill kits and personal protective equipment) in the lab to respond to a minor spill, learning how to safely clean up minor spills of the chemicals used regularly and what to do if there were a leak from a compressed gas cylinder or piped gas.

If the release or 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

Chemical spills should only be cleaned up by trained, knowledgeable and experienced personnel.

Trained laboratory personnel can clean-up most minor spills without direct EHS assistance by following the procedure below, if they are comfortable doing so and fully understand the hazards of the spilled material and methods to protect themselves. An SDS contains special spill clean-up information and should also be consulted. 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 the Safety Data Sheet (SDS) 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 Laboratory Hazard Assessment Tool.
- Use appropriate kit to absorb or neutralize spilled material. Work from perimeter inwards. Collect residue with scoop or dust pan, 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 mercury.
- 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.

2.5.6 Compressed Gas Leak

If a cylinder leak cannot be stopped by tightening the valve gland or packing nut, follow the appropriate guidelines below:

- **Inert gas:** Place the cylinder in a well-ventilated location and contact the vendor for removal.
- **Toxic or Corrosive gas:**
 - Attend to injured or contaminated persons and remove them from exposure.
 - Alert people in the laboratory to evacuate.
 - 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.
- **Flammable gas:**
 - Turn off sources of ignition if safe to do so.
 - Alert people in the laboratory to evacuate.
 - 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.

2.6 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:

Yale University Police (ambulance)	911 (from a Yale phone) or 203-432-4400
Yale Health Acute Care (minor medical)	203-432-0123
Yale EHS Hazardous Materials Emergency Response	203-785-3555

2.6.2 Chemicals Spills to the Body

- Remove any contaminated clothing or footwear.
- Immediately flood the affected body area with 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 (eg. 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 to 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 gel

readily available. The Office of Environmental Health and Safety currently purchases and distributes the gel 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 15 minutes with cool flowing water. Hold the eyelids open and away from the eye during irrigation to allow thorough flushing of the eyes.
- Contact 911 and inform dispatcher that eye exposure involves HF.
- Continue to rinse in eyewash until EMS arrives.

2.6.8.3 Inhalation Exposures to HF

- Move inhalation exposure victim to clean air.
- 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 OTHER RELATED EMERGENCIES

If you discover a fire or smoke, immediately follow these procedures:

- Notify the Fire Department by dialing 911
- Activate the building alarm (fire pull station).
- Shut down equipment in the immediate area, if possible.
- Isolate the area by closing windows and doors and evacuate the building.
- 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 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.

If you notice/discover a natural gas leak, burning odor, or abnormal heating of material, immediately follow these procedures:

- Notify the Facilities Operations at 203-432-6888;
- Shut down equipment in the immediate area, if possible;
- If a building natural gas leak is suspected, use emergency gas shut-off for the affected area;
- Evacuate the area.

2.8 CHEMICAL WASTE DISPOSAL PROGRAM

Laboratory chemical waste must be handled according to the University's policy and management guidelines outlined in the *Management of Hazardous Waste Procedure* which can be found at ehs.yale.edu. 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.

SECTION 3.0 HEALTH AND SAFETY INFORMATION FOR WORK WITH CHEMICALS OF SPECIFIC HAZARD CLASS

In addition to the information in the following section, general guidance on safe work practices involving a specific chemical or hazard class can be found at <https://ehs.yale.edu/restricted-particularly-hazardous-substances> for the following:

Acrolein	Acutely Toxic Materials	Aqua Regia
Carcinogens	Corrosives	Flammable Liquids
Hydrofluoric Acid	Isoflurane	Osmium Tetroxide
Organic Peroxides and Peroxide Forming Compounds	Phenol	Piranha
Potassium or Sodium Cyanide	Potentially Explosive and Explosive Compounds	Pyrophoric & Water Reactive Compounds
Sodium Azide	Strong Oxidizers	Tetramethylammonium Hydroxide
(Trimethylsilyl) Diazomethane		

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

When working with flammable liquids, chemical resistant gloves, safety glasses or goggles, and lab coats must be worn. Long pants or clothing that covers the legs and closed-toe, solid top shoes must 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 faceshield 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, or on a shelf below eye level. Five-gallon containers should only be stored in a flammable cabinet.

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 directly on the floor.

Oxidizing and corrosive materials should not be stored with flammable liquids. A tray could be used to separate containers if necessary. 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 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 vinylidene compounds.

3.2.2 Special Handling Procedures for Highly Reactive Compounds

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: lab coats, chemical resistant gloves and safety glasses/goggles. Long pants or clothing that covers the leg to the ankles and closed-toe, solid top shoes must always be worn when working with hazardous materials in the laboratory. A face 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 Laboratory Hazard Assessment Tool to determine the appropriate personal protective equipment for the 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.

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.

Labels on peroxide forming and shock/heat sensitive substances should contain the date the container was received and first opened. Information on proper use, testing and storage of these chemicals can be found in the “Peroxide Forming Chemicals” safety guidelines at ehs.yale.edu. 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 ($\geq 72\%$) 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.

3.2.4 Special Handling Procedures for Pyrophoric and Water Reactive 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. Purchases of pyrophoric chemicals are flagged as Restricted and are routed to EHS for approval.

Basic rules for working with pyrophoric chemicals at 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” made of aramid fiber should be worn. These are not chemically resistant but could be worn over exam style nitrile gloves. Flame resistant lab coats and flight gloves are available through Workday. The Laboratory Hazard Assessment Tool should be used to determine the appropriate personal protective equipment requirements. Contact EHS for more information.

Look to use materials that are less reactive whenever possible.

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.

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 credit for the online training “Working Safely with Organolithium Compounds” which can be found on the Yale EHS website (ehs.yale.edu).
- Dispose of container as hazardous waste within 1 month of opening.
- Only purchase the amount that you plan to use for each experiment.
- 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 shield 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, solid top shoes when handling compressed gases. Refer to the Laboratory Hazard 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 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 may also need to be stored in a ventilated gas cabinet. 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.

Compressed Gas	CGA number	Compressed Gas	CGA number
Argon	580	Freon	660
Carbon dioxide	320	Helium	580
Carbon monoxide	350	Hydrogen	350
Chlorine	660	Hydrogen chloride	330
Ethane	350	Nitrogen	580
Ethylene	350	Oxygen	540

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 Toxic, Corrosive and Flammable Gases

Toxic, corrosive and a subset of flammable gases are restricted chemicals and require EHS approval prior to purchase and must be registered into the Yale chemical registration program. Many of these gases are also regulated under the Department of Homeland Security. (See Section 3.6)

Toxic, corrosive and pyrophoric gases must be stored and used under local exhaust ventilation, either in an exhausted gas cabinet or another exhausted enclosure approved by EHS. A continuous 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.

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

3.4 CORROSIVE CHEMICALS

3.4.1 General Information

Corrosive chemicals can be both a health hazard and a physical hazard. 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, 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. 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 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 initially 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 or other local exhaust ventilation. 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

When working with corrosive chemicals wear appropriate gloves, safety glasses or goggles, long sleeved lab coat and closed-toe, solid top 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 Laboratory Hazard 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 there is a possibility of dripping or spillage.

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 as much as possible.

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.

3.5.2 Special Handling Procedures

An SOP should be available and reviewed by the PI or designated senior lab personnel for work involving these materials.

Avoid or minimize contact with these chemicals by any route of exposure. Protect yourself by wearing gloves, long pants, closed-toe, solid top 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 Laboratory Hazard 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, place in a plastic bag and secure 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 have the ability to be easily decontaminated or protected from contamination with plastic trays or plastic backed paper. Refer to the SDS or contact Environmental Health and Safety for substance-specific decontamination and disposal procedures.

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.

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.

Highly toxic chemicals are flagged as restricted and routed to EHS for approval. The list of restricted chemicals, which includes highly toxic chemicals, is located at <http://ehs.yale.edu/forms-tools/chemicals-requiring-ehs-pre-approval>. An inventory of these chemicals are maintained in Yale's chemical inventory system. An SOP is required for all work involving highly toxic chemicals.

Examples of carcinogens and reproductive toxins are listed in Appendix K. Some of these chemicals are also flagged as restricted and routed to EHS for approval. SOPs are 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 (CFATS) Interim Final Rule, have mandated that all workplaces, including universities, inventory and report on the presence and location of specific "chemicals of interest". These chemicals are identified 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. The chemicals on the CFATS Chemicals of Interest list can be found here: <https://www.cisa.gov/appendix-chemicals-interest>.

3.6.2 Special Handling Procedures

The chemicals on this list may present one or more of hazardous characteristics outlined previously, i.e., flammable, acutely toxic, etc. The hazard(s) of the chemical being used should be understood prior to beginning work and the appropriate procedures for those hazards outlined in previous subsections should be followed.

Access to all these chemicals should be restricted. They should not be stored on open shelves or counters. Volatile chemicals should be stored in an appropriately rated cabinet (corrosive, flammable). Nonvolatile hazardous chemicals should be stored in cabinets or in drawers.

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

SOPs are required for all work involving these chemicals.

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 (or systemic) exposure for a substance is through skin contact, the SDS, 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 effect**. Similarly, a **potentiating effect** occurs when a substance normally has no toxic effect, but becomes toxic in the presence of another substance. Examples include: 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 | - Tetraethyl lead |
| - Methyl mercury | - Carbon disulfide |
| - Organic phosphorus insecticides | - Thallium |
| - 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	Methyl chloromethyl ether
Formaldehyde	Benzene
Vinyl chloride	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.

Toxins	Target organ effect	Signs and symptoms	Example chemicals
Hepatotoxins	Cause liver damage	Jaudice; liver enlargement	Nitrosamines, chloroform, toluene, perchloro-ethylene, cresol, dimethylsulfate, carbon tetrachloride
Nephrotoxins	Cause kidney damage	Edema; proteinuria	Halogenated hydrocarbons, uranium, chloroform, mercury, dimethylsulfate
Neurotoxins	Affect the nervous system	Narcosis; behavior changes; decreased muscle coordination	Mercury, carbon disulfide, benzene, carbon tetrachloride, lead, nitrobenzene

Hematopoietic toxins	Decrease blood function	Cyanosis; loss of consciousness	Carbon monoxide, cyanides, nitro-benzene, aniline, arsenic, benzene, toluene
Pulmonary toxins	Irritate or damage the lungs	Cough; tightness in chest, shortness of breath, pulmonary edema	Silica, asbestos, ozone, hydrogen sulfide, chromium, nickel, alcohols
Reproductive toxins	Affect the reproductive system	Birth defects; sterility	Lead, 2-ethoxyethanol, dibromodichloropropane, toluene
Skin hazards	Affect the dermal layer of the body	Defatting of skin; rashes; irritation	Ketones, chlorinated compounds, alcohols, nickel, phenol, trichloroethylene
Eye hazards	Affect the eye or vision	Conjunctivitis, corneal damage	Organic solvents, acids, cresol, quinone, hydroquinone, benzol, chloride, butyl alcohol, methanol, bases

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 of 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 hazardous component of a mixture.

The Environmental Health and Safety office 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 Environmental Health and Safety. The list of available references in the Environmental Health and Safety office 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.

ASPHYXIAN - 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 causing 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. Adequate oxygen levels range from 19.5 to 23.5%.

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, friction, or shock, will usually be specified as "Conditions to Avoid" when a chemical's reactivity is discussed on a SDS.

RESPIRATOR - A form of PPE which is designed to protect the wearer from inhaling harmful contaminants.

RESPIRATORY HAZARD - A particular concentration of an airborne contaminant that, when entering 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 with continued exposures over time, 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. 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.

"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 EHS Safety Advisor can also provide a copy upon request.

APPENDIX B YALE UNIVERSITY POLICY ON EATING, DRINKING AND SMOKING IN LABORATORIES

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, not 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.* On a case-by-case basis, exceptions to this restriction may be made for covered beverages in interior office spaces not meeting all of these requirements, upon formal request for review by Environmental Health and Safety. Laboratories with infectious agents or radioactive materials are prohibited from this exception.

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.

Notes:

* 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.
- Bretherick, L. (ed.). *Handbook of Reactive Chemical Hazard*, 6th edition. Butterworth Heinemann. 1999.
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- Klaassen, CD (ed.). *Casarett & Doull's Toxicology: The Basic Science of Poisons*, 5th ed. McGraw-Hill Co., 1996.
- Manufacturing Chemists Association. *Guide for Safety in the Chemical Laboratory*, 2nd ed. Van Nostrand Reinhold Co., 1972.
- National Research Council. *Prudent Practices in the Laboratory. Handling and Disposal of Chemicals*. National Academy Press, Washington, DC. 1995.
- Sax, N.J. and Lewis, R.J. (ed.). *Rapid Guide to Hazardous Chemical in the Workplace*. Van Norstrand Reinhold Company, New York. 1986.
- U.S. Department of Health and Human Services. *NIOSH Pocket Guide to Chemical Hazards*.
- 29CFR1910 Code of Federal Regulations, United States Department of Labor, OSHA.

APPENDIX D 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 Regular _____
Impervious _____
Boots _____
Coveralls _____
Apron Impervious _____
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)

Corrosive

Toxic

Reactive

Flammable

Pressurized

Water Reactive

Electrical

In Case of Emergency Shut off:

Electricity

Vacuum

Gas Source

Water Source

Hot Plate/Ignition Sources

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 F 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):

Substances Used	Approx. quantity	Physical form i.e. powder, vapour, volatile liquid, gas, etc	Hazards i.e. flammable, corrosive, irritant, readily absorbed through skin, etc.	Exposure route(s) e.g. skin, eyes

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 <input type="checkbox"/> Chemical fume hood <input type="checkbox"/> Glove box <input type="checkbox"/> Other local exhaust ventilation <input type="checkbox"/> Blast guard/shield <input type="checkbox"/> Other (specify)	Personal Protective Equipment <input type="checkbox"/> Lab coat (type): <input type="checkbox"/> Chemical apron <input type="checkbox"/> Gloves (type): <input type="checkbox"/> Eye protection (type): <input type="checkbox"/> Respiratory protective equipment * (type): <input type="checkbox"/> 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:

Major Laboratory Equipment Used	Potential Hazards (i.e. electric shock, temperature extremes, pressure, chemical exposure)

Equipment controls required?**Disposal measures to be used during and after the procedures:****Emergency procedures** (emphasize 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 G SELECTION AND USE OF PERSONAL PROTECTIVE EQUIPMENT

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

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:

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
✓	Working in a laboratory where hazardous materials are used <i>(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)</i>	<ul style="list-style-type: none">Contamination (feet, leg, clothing, eyes, hands)	<ul style="list-style-type: none">Closed-toe, solid top shoesClothing that covers the legsSafety glasses or prescription glassesGloves if touching potentially contaminated equipment

Additional Personal Protective Equipment Requirements:

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Directly handling hazardous materials	<ul style="list-style-type: none">Chemical, biological or radioactive material contamination (hands, eyes)Contamination of personal clothing or skin (body)	<ul style="list-style-type: none">Safety glassesGloves—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	<ul style="list-style-type: none">Splashing (eyes, face)Contamination/burns to unprotected skin (hands, wrists, body)	<ul style="list-style-type: none">Chemical gogglesFace shield if under pressure or outside fume hoodGloves—utility grade nitrile or neoprene over nitrile exam styleLab coat

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Working directly with pyrophoric and water reactive chemicals	<ul style="list-style-type: none"> Burns (clothing, eyes, face, hands, body) 	<ul style="list-style-type: none"> 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
	Working with cryogenic materials	<ul style="list-style-type: none"> Cold burns (eyes, face, hands, body) 	<ul style="list-style-type: none"> Safety glasses Face shield (larger volumes) Thermal insulated gloves Lab coat, apron or equivalent (larger volumes)
	Working with hot objects or equipment	<ul style="list-style-type: none"> Burns (eyes, face, hands, body) 	<ul style="list-style-type: none"> Safety glasses Face shield as necessary Heat resistant gloves Lab coat, apron or equivalent
	Working with apparatus under high pressure	<ul style="list-style-type: none"> Cuts from glass/ material fragments (face, hands, body) Chemical contamination (eyes, face, hands, body) 	<ul style="list-style-type: none"> Safety glasses or goggles Face shield Utility gloves Rubber apron as necessary Portable blast shield as necessary
	Working with highly reactive or explosive chemicals	<ul style="list-style-type: none"> Cuts from glass/ material fragments (face, hands, body) Chemical contamination (eyes, face, hands, body) Fire 	<ul style="list-style-type: none"> 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

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Minor chemical spill cleanup (if <1 liter of low hazard chemical, and respiratory protection is not required)	<ul style="list-style-type: none"> Chemical contamination (shoes, eyes, hands, clothing) 	<ul style="list-style-type: none"> Shoe covers as necessary Safety glasses or goggles Double nitrile gloves or utility grade gloves over nitrile exam gloves Lab coat
	UV light sources	<ul style="list-style-type: none"> Burns (eyes, face, neck, hands, wrist) 	<ul style="list-style-type: none"> Full face shield (polycarbonate) over safety glasses Nitrile gloves (wrists fully covered) Lab coat
	Handling animals in a laboratory	<ul style="list-style-type: none"> Animal blood and other potentially infectious materials (eyes, hands) Bites, scratches (hands, forearms, body) Allergens (respiratory or transfer to mucous membranes of the eyes, nose or mouth) Anesthetic agents (respiratory) 	<ul style="list-style-type: none"> Safety glasses Gloves Gown or lab coat Refer to YARC for additional PPE requirements, which may differ depending on species, engineering controls, and hazardous agents used
	Working with radioactive materials	<ul style="list-style-type: none"> Contamination of personal clothing (body) Radioactive material contamination (eyes, hands, wrists, skin) 	<ul style="list-style-type: none"> Safety glasses Gloves (double gloves recommended) Lab coat Personal radiation badge as appropriate Survey meter as appropriate Bench-top radiation shielding as appropriate
	Performing an iodination with volatile radioactive sodium iodide inside an approved radioiodine fume hood	<ul style="list-style-type: none"> Contamination of personal clothing (shoes, body) Radioactive material contamination (eyes, hands, wrists, skin) Inhalation of volatile material (respiratory) 	<ul style="list-style-type: none"> Shoe covers Safety glasses Double gloves Sleeve covers Lab coat Personal radiation badge Survey meter with scintillation probe Benchtop radiation shielding

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Working at a microscope in the laboratory	<ul style="list-style-type: none"> • Hazard material contamination (hands) • Contamination of personal clothing (body) 	<ul style="list-style-type: none"> • (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.)	<ul style="list-style-type: none"> • 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) 	<ul style="list-style-type: none"> • 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

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Working with open table Class 3B or 4 Lasers	<ul style="list-style-type: none"> • Ocular and skin exposure (eyes, face, hands, body) 	<ul style="list-style-type: none"> • 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

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
<p>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</p> <p>For other experiments, researchers can refer to the Gradations of Risk Table referenced in this document.</p>			
	<p>Work with Risk Group 1 materials that do not cause disease in humans (i.e. non-pathogenic strains of <i>E. coli</i>, <i>Bacillus subtilis</i>, <i>Saccharomyces cerevisiae</i>, rodent cell lines)</p>	<ul style="list-style-type: none"> • Risk Group 1 materials could represent a risk to individuals with compromised immunity or who may have allergies to the materials (eyes, hands, respiratory, body) 	<ul style="list-style-type: none"> • Safety glasses • Gloves • Lab coat • Surgical mask or respirator, if specified

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Working with human blood, tissues, body fluids, human cell lines, or Risk Group 2 bloodborne pathogens, utilizing Universal Precautions and BSL2 containment.	<ul style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> 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 <i>Plasmodium falciparum</i> , <i>Salmonella typhimurium</i> , Herpes Simplex Virus and <i>Cryptococcus neoformans</i>)	<ul style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> 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, <i>Mycobacterium tuberculosis</i> , <i>Histoplasma capsulatum</i>) in cell culture or laboratory animals	<ul style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> 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.

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	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.	<ul style="list-style-type: none"> All routes of exposure (percutaneous, inhalation, ingestion, and via facial mucous membranes) may be involved with these experiments. 	<ul style="list-style-type: none"> Work with Risk Group 4 Agents is not allowed at Yale University.

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:	
Signature	Date
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.	
Signature of EHS Approver :	Date of Approval:

APPENDIX H HIGHLY REACTIVE COMPOUNDS AND STRONG OXIDIZERS

Examples of potentially explosive and explosive compounds include:

Potentially Explosive Compounds (PEC)

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

Potentially Explosive Compound Classes

Acetylene (-C≡C-)	Acyl hypohalites (RCO-OX)	Azide Organic (R-N ₃)
Azide Metal (M-N ₃)	Azo (-N=N-)	Diazo (=N=N)
Diazosulphide (-N=N-S-N=N-)	Diazonium salts (R-N ₂ ⁺)	Fulminate (-CNO)
Halogen Amine (=N-X)	Nitrate (-ONO ₂)	Nitro (-NO ₂)
Aromatic or Aliphatic Nitramine (=N-NO ₂) (-NH-NO ₂)	Nitrite (-ONO)	Nitroso (-NO)
Ozonides	Peracids (-CO-O-O-H)	Peroxide (-O-O-)
Hydroperoxide (-O-O-H)	Metal peroxide (M-O-O-M)	

Explosive Salts

Bromate salts (BrO ₃ ⁻)	Chlorate salts (ClO ₃ ⁻)	Chlorite salts (ClO ₂ ⁻)
Perchlorate salts (ClO ₄ ⁻)	Picrate salts (2,4,6-trinitrophenoxide)	Picramate salts (2-amino-4,6-dinitrophenoxide)
Hypohalite salts (XO ⁻)	Iodate salts (IO ₃ ⁻)	

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)
- Manganese 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)

APPENDIX I CHEMICALS THAT MAY FORM EXPLOSIVE PEROXIDES

(This list is not all inclusive)

Class A Chemicals which may form explosive peroxides without concentration. <i>Discard within 3 months after opening</i>	Class B Chemicals which may form peroxides upon concentration (distillation/evaporation). <i>Discard within 12 months after opening</i>	Class C Chemicals that may autopolymerize as a result of peroxide accumulation. <i>Discard within 12 months after opening</i>
Isopropyl ether	Acetal	Acrylic acid
Butadiene (liquid)	Cumene	Butadiene (gas)
Chlorobutadiene (chloroprene)	Cyclohexene	Chlorotrifluoroethylene
Potassium amide	Cyclooctene	Ethyl acrylate
Potassium metal	Cyclopentene	Methyl methacrylate
Sodium amide (sodamide)	Diacetylene	Styrene
Tetrafluoroethylene	Dicyclopentadiene	Vinyl acetate
Divinyl acetylene	Diethylene glycol dimethyl ether (diglyme)	Vinyl acetylene
Vinylidene chloride	Diethyl ether	Vinyl chloride
	Dioxane (p-dioxane)	Vinyl pyridine
	Furan	
	Methyl acetylene	
	Methyl cyclopentane	
	Methyl-i-butyl ketone	
	Tetrahydrofuran	
	Tetrahydronaphthalene	
	Vinyl ethers	

National Research Council, *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards*; National Academies Press: Washington DC, 2011; pg 72.

APPENDIX J RESTRICTED CHEMICALS REQUIRING EHS APPROVAL

The most updated list can be found on this page:

<https://ehs.yale.edu/sites/default/files/files/chemicals-ehs-approval.pdf>

APPENDIX K CARCINOGENS AND REPRODUCTIVE TOXINS

(This list is not all inclusive)

Chemical	CAS
1,1-dimethylhydrazine (UDMH)	57-14-7
1,2-Dibromo-3-chloropropane	96-12-8
1,2-dichloroethane	107-06-2
1,3-butadiene	106-99-0
1,3-Propane sultone	1120-71-4
1,4-dioxane (p-dioxane)	123-91-1
1,4-Butanediol dimethanesulfonate (myleran, busulfan)	55-98-1
1-Methyl-3-nitro-1-nitrosoguanidine (MNNG)	70-25-7
2-Acetylaminofluorene	53-96-3
2-Aminofluorene	153-78-6
2-Ethoxyethanol (ethyl cellosolve)	110-80-5
2-Ethoxyethylacetate (cellosolve acetate)	111-15-9
2-Methoxyethanol (methyl cellosolve)	109-86-4
2-Methoxyethylacetate (methyl cellosolve acetate)	110-49-6
2-naphthylamine	91-59-8
2-nitropropane	79-46-9
3-Methylcholanthrene	56-49-5
3,3'-Dichlorobenzidine (& its salts)	91-94-1
3,3'-Dimethylbenzidine (o-Tolidine)	119-93-7
4,4'-Methylene bis(2-chloroaniline) (MOCA)	101-14-4
4,4-methylenedianiline	101-77-9
4-Aminodiphenyl	92-67-1
4-Dimethylaminoazobenzene (p-dimethylaminoazobenzene)	60-11-7
4-Nitrobiphenyl	92-93-3

Chemical	CAS
cobolt and cobolt compounds	varies
Cyclophosphamide	50-18-0
Diazoaminobenzene	136-35-6
Dibenz[a,h]anthracene	53-70-3
Diepoxybutane	1464-53-5
Diethylstilbestrol (DES)	56-53-1
Diethyl sulfate	64-67-5
Dimethyl sulfate	77-78-1
Ethyl methanesulfonate	62-50-0
Ethylene dibromide	106-93-4
Ethyleneimine	151-56-4
Ethylene oxide	75-21-8
Formaldehyde (formalin)	50-00-0
Furan	110-00-9
hexamethylphosphoramide	680-31-9
Hydrazine	302-01-2
isoprene	78-79-5
lead and lead compounds	varies
Methylmercury and other organic mercury compounds	varies
Methyl methanesulfonate	66-27-3
Methylene chloride (dichloromethane)	75-09-2
Methyl chloromethyl ether	107-30-2
Nickel and nickel compounds	varies

Chemical	CAS
7,12-Dimethylbenz[a]anthracene	57-97-6
Acetaldehyde	75-070-0
Acrylamide (solid form)	79-06-1
Acrylonitrile	107-13-1
alpha-Naphthylamine (1-Naphthylamine)	134-32-7
Arsenic and arsenic compounds	varies
Benz[a]anthracene	56-55-3
Benzene	71-43-2
Benzidine	92-87-5
Benzo[a]pyrene	50-32-8
beryllium	7440-41-7
Beryllium compounds	varies
beta-Naphthylamine (2-Naphthylamine)	91-59-8
beta-Propiolactone	57-57-8
bis-chloromethyl ether	542-88-1
bromodichloromethane	75-27-4
Cadmium and cadmium compounds	varies
Carbon tetrachloride	56-23-5
Chemotherapy agents	varies
Chlornaphazine	494-03-1
Chloroethylene (vinyl chloride)	75-01-4
Chloroform	67-66-3
chromium compounds (VI)	varies

Chemical	CAS
Nitrobenzene	98-95-3
Nitromethane	75-52-5
N,N-bis(2-chloroethyl)-2-naphthylamine (chlornaphazine)	494-03-1
N-Nitrosodiethylamine	55-18-5
N-Nitrosodimethylamine	62-75-9
N-Nitrosodi-n-butylamine	924-16-3
N-Nitrosodi-n-propylamine	86-30-6
N-Nitroso-N-ethylurea	759-73-9
N-Nitroso-N-methylurea	684-93-5
N-Nitroso-N-methylurethane	615-53-2
N-Nitrosopiperidine	100-75-4
o-Aminoazotoluene	97-56-3
Perchloroethylene	127-18-4
Polychlorinated biphenyls (PCBs)	varies
propylene oxide (epoxypropane)	75-56-9
Propylenimine (2-methylaziridine)	75-55-8
Styrene	100-42-5
Thioacetamide	62-55-5
Toluene diisocyanates (TDI)	26471-62-5
trichloroethylene (TCE)	79-1-6
Uracil mustard	66-75-1
Urethane (ethyl carbamate)	51-79-6
vinyl magnesium bromide	1826-67-1