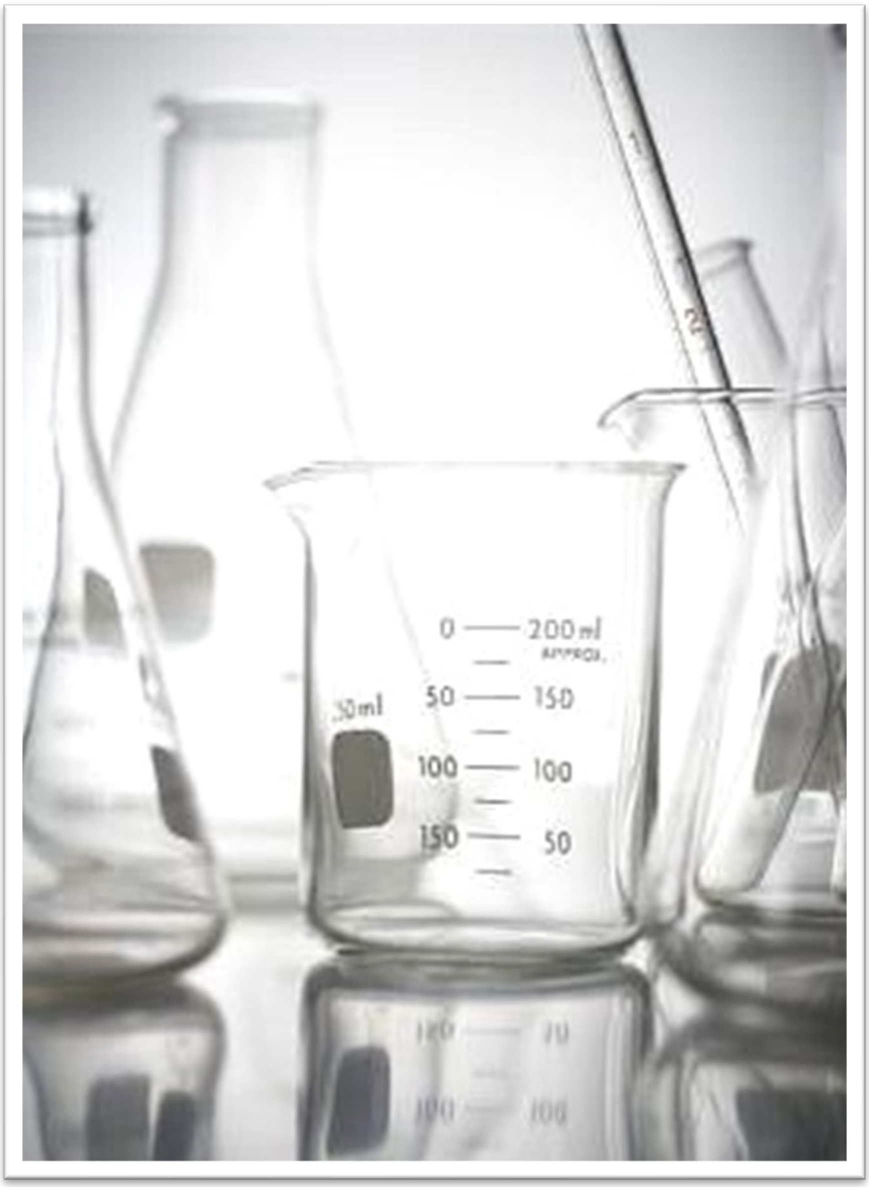
Yale University
Office of Environmental Health & Safety

Laboratory Chemical Hygiene Plan



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SECTION 1.0 YALE UNIVERSITY LABORATORY CHEMICAL HYGIENE PLAN

1.1 INTRODUCTION

The Chemical Hygiene Plan (CHP) is a requirement for non-production laboratories where chemicals are used in accordance with the Occupational Safety & Health Administration's (OSHA) Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450), more commonly referred to as the Laboratory Standard. This plan applies to all Yale University faculty, staff, students, and visitors who use hazardous materials in laboratory settings.

The CHP does not address the use of radioactive materials or biological agents. Information on these materials is available in the University's Radiation Safety Manual and Biosafety Manual, respectively. Where additional regulatory standards apply (e.g., CLIA, CAP, Radiation Safety, Biosafety), this Plan supplements those requirements. The most protective standard governs.

OSHA's Laboratory Standard requires employers of laboratory personnel to implement exposure control programs that convey chemical health and safety information to laboratory personnel working with hazardous materials. Specific provisions of the standard require:

- laboratory inspections;
- establishment of standard operating procedures for routine and high-hazard laboratory operations;
- protocol safety reviews for procedures, activities, or operations that the employer believes to be of sufficiently hazardous nature to warrant prior approval;
- exposure assessments;
- medical consultations/exams;
- training;
- labeling of chemical containers;
- the management of chemical safety data and other safety reference materials.

The intent of this standard is to ensure that laboratory personnel 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. Yale's Chemical Hygiene Plan covers all personnel in laboratories at the University, including faculty, staff, and students.

The standard operating procedures (laboratory practices and engineering controls) recommended in this plan specify the safeguards to be implemented when handling hazardous chemicals. These safeguards will protect laboratory personnel from unsafe conditions in most 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 are such that additional or fewer controls may be appropriate to protect the laboratory worker. Professional judgment is essential when interpreting these standard operating procedures, and individual laboratories may modify them to meet their specific uses and operational needs. These modifications and lab-specific SOPs must be maintained by the laboratory and be 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 Chemical Hygiene Plan. This plan is available on the Yale Environmental Health and Safety (EHS) website: ehs.yale.edu. Printed copies can be made available by contacting EHS (203-785-3550). OSHA's

Exposure to Hazardous Chemicals in Laboratories standard and appendices (29 CFR 1910.1450) are available on the OSHA website: https://www.osha.gov/

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, Director, or Manager who has 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 personnel 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 personnel in the laboratory to ensure the required safety and chemical hygiene rules are adhered to;
- Completing required EHS training, and ensuring that all lab personnel also complete required EHS training;
- Ensuring appropriate controls (engineering and personal protective equipment) are used and are in good working order;
- Obtaining approval, when required, from Yale EHS prior to purchasing and using particularly hazardous substances;
- Developing an understanding of the current legal requirements regulating hazardous substances used in the 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 are 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 EHS;
- Completing all required EHS 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, Managers and Supervisors 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, Managers and Supervisors 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.

Laboratory Safety Committee, which is responsible for:

- Providing subject matter expertise on laboratory safety issues to the University;
- Evaluating, assisting, and advising on laboratory safety issues not covered by other institutional safety committees, such as the BSC and RSC;
- Providing guidance and support to the Chemical Hygiene Officer (CHO) and EHS in executing the University's Chemical Hygiene Plan;
- Examining laboratory-related policies and approval processes for minors, undergraduates, graduate students, post-doctoral scientists, fellows, visiting scientists, researchers, and others in Yale laboratories.

1.3 KEY DEFINITIONS

Additional terms are defined in SECTION 5.0 GLOSSARY OF TERMS.

1.3.1 Laboratory

A facility in which hazardous chemicals (defined below) are used in small quantities (containers that are easily manipulated by one person) on a non-production basis.

1.3.2 Laboratory Personnel

Laboratory personnel include faculty, staff, students, trainees, clinical laboratory staff, conservation professionals, visiting scholars, contractors, and any other individuals who work in Yale laboratories where hazardous chemicals are used or stored.

1.3.3 Hazardous Chemical

Any chemical that is classified as a health hazard or simple asphyxiant in accordance with the Hazard Communication Standard (§ 1910.1200).

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

For purposes of this plan, it also includes any chemical that is a physical hazard. This includes chemicals which are:

- combustible
- explosives
- organic peroxides
- oxidizers
- pyrophoric
- flammable
- reactive
- compressed gas

In most cases, the chemical container's original label indicates whether the chemical is hazardous. OSHA's Hazard Communication Standard requires chemical labels and safety data sheets to be uniform and consistent with global regulations. There are signal words (Warning, Danger), hazard statements, precautionary statements, and pictograms based on the chemical's hazard classification. Note that products manufactured beginning June 2015 were required to be labeled in compliance with this regulation; containers of hazardous chemicals acquired or manufactured before June 2015 may not contain this standardized information. These containers will still indicate the contents and hazard warnings. Look for keywords like caution, hazardous, toxic, dangerous, corrosive, irritant, carcinogen, etc.

To confirm if a chemical you are using is hazardous, review the SDS for the substance or contact your supervisor, instructor, or EHS Safety Advisor.

1.4 HAZARD IDENTIFICATION FOR NEWLY SYNTHESIZED CHEMICALS

Some laboratories synthesize or develop new chemical substances during their work. If the composition of the substance is known and will be used exclusively in the laboratory, laboratory personnel must label the substance and, to the best of their ability, determine its hazardous properties (e.g., corrosive, flammable, reactive, toxic, etc.). 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 must provide as much information as possible about the substance's identity and known hazardous properties to the recipient. This should be communicated in the form of a hazard information sheet as illustrated in the sample form in APPENDIX D PRELIMINARY HEALTH AND SAFETY INFORMATION SHEET. Contact EHS if you have questions or need assistance with meeting this obligation.

1.5 TRAINING & INFORMATION

1.5.1 Laboratory Safety Training

All laboratory personnel exposed to, or potentially exposed to, hazardous chemicals while performing their laboratory duties must receive information and training on the standard, this Chemical Hygiene Plan, and laboratory safety prior to working with these chemicals and every three years thereafter. This training program, entitled *Laboratory Safety*, must be completed in Workday Learning. Principal Investigators, Managers, and Supervisors are responsible for the safety in their laboratories and must also receive this information and complete this training. Additional laboratory-specific safety training is provided by the Principal Investigator, Manager, or Supervisor.

All laboratory personnel must complete the *Laboratory Safety Program* prior to beginning work with hazardous chemicals. When performing a non-routine task that presents hazards for which laboratory personnel have not already been trained, the supervisor will discuss the task hazards and any special measures (e.g., personal protective equipment or engineering controls) to be used with the affected person. Environmental Health and Safety is available for consultation as needed. Information on Personal Protective Equipment (PPE) for specific laboratory tasks is available in the Yale University PPE Assessment Tables/Tools for Laboratories. Every laboratory member should know the locations and proper use of available protective clothing and equipment, as well as emergency equipment/procedures. Additional information on protective clothing and equipment is also contained in SECTION 2.3 PROTECTIVE CLOTHING AND LABORATORY SAFETY EQUIPMENT of this manual.

1.5.2 Chemical Safety Information Sources

There are numerous sources of chemical safety information available online and on campus. These sources include:

(1) labels found on containers of hazardous chemicals;
(2) the substance's SDS;

(3) special health and safety reference literature available online;
(4) reference literature available from EHS; and
(5) signs, charts, and fact sheets available from EHS 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 an SDS management system. Supplier/manufacturer-specific SDS can be obtained via this system, accessible from any Yale IP address via the Yale EHS website at ehs.yale.edu. Yale EHS also maintains a library of reference materials on chemical health and safety. 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 hazardous chemicals must not be removed or defaced except when empty.

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 for handling the material, first-aid instructions, storage information, and procedures to follow in the event of a fire, leak, or spill. All labels on chemicals purchased after June 2015 must include the information required by 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 ensures consistent, uniform hazard information across all chemical containers, regardless of manufacturer or supplier.

Read the label each time you use a newly purchased chemical. The manufacturer may have added new hazard information or reformulated the product since your last purchase, which could have altered the potential hazards you face when working with it.

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 EHS should be notified if containers lack proper labels.

Secondary working containers that will not be immediately used should also be labeled:

- Labels on containers used for storing hazardous chemicals should include the chemical or product identification and appropriate hazard warnings. Appropriate hazard warnings can be included on the secondary container itself, in a laboratory posting outlining chemicals and their hazards, or through another comparable method.[1]
- The contents of all other chemical containers and transfer vessels, including, but not limited to, beakers, flasks, reaction vessels, and process equipment, should be properly identified

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 that describes the physical and chemical properties of the product. Information in these data sheets aids in selecting safe products, helps personnel understand the potential health and physical hazards of the

[1] Labeling of secondary containers with hazard information is required in laboratories that are subject to the Hazard Communication Standard or a certifying agency that mandates this information.

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 chemical or compound's hazard classification and category. If you have safety questions regarding a particular chemical, contact EHS or your supervisor.

The University maintains an SDS management system accessible via the EHS website when connected to the Yale network.

If you do not have web access or need a hard copy of an SDS, EHS will provide one upon request at no charge. Your laboratory supervisor may also maintain SDSs for chemicals commonly used in your laboratory. Alternatively, you may request an SDS directly from the chemical manufacturer or supplier.

As of June 2015, all chemical manufacturers and importers were required to provide SDSs that comply with the updated Hazard Communication Standard. When referencing an SDS, ensure it is dated June 2015 or later to confirm it meets these requirements.

The 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; ACGIH TLVs; appropriate engineering controls; personal protective equipment (PPE).
- Section 9: Physical and chemical properties lists the chemical's characteristics.
- Section 10: Stability and reactivity lists chemical stability and possibility of hazardous reactions.
- Section 11: Toxicological information includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.
- Section 12: Ecological information
- Section 13: Disposal considerations
- Section 14: Transport information
- Section 15: Regulatory information
- Section 16: Other information**,** includes the date of preparation or last revision.

If you would like additional information concerning the content or use of SDSs, contact your supervisor or EHS.

1.5.2.3 Signage

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 lab, safety equipment available in the lab, restrictions on entering the laboratory, and the names and phone numbers of the Principal Investigator/Director/Supervisor and other responsible laboratory personnel. These postings are kept up to date and used by emergency responders in the event of an emergency when the laboratory is unoccupied.

- 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 periods, in small quantities, and/or within laboratory fume hoods or other local exhaust ventilation systems. Exposure monitoring may be appropriate when a highly toxic substance is used regularly or for an extended period, when hazardous chemicals are used outside a fume hood/local exhaust ventilation, or when quantities are larger than lab-scale. During annual laboratory safety inspections, Safety Advisors from EHS will identify these situations, and Industrial Hygienists from Yale EHS will perform follow-up exposure assessments as necessary.

The EHS Industrial Hygienists will assess exposures for laboratory personnel who suspect or report being overexposed to a toxic chemical in the laboratory or who are displaying symptoms of overexposure. The assessment may include specific quantitative exposure monitoring. These results and any corresponding recommendations will be sent to the laboratory Principal Investigator/Director/Supervisor, the Employee Health Physician or Other Licensed Health Care Professional (PLHCP), the affected laboratory personnel, and anyone else deemed appropriate. A copy of the monitoring results will be kept on file in the EHS Office.

Individuals with concerns about laboratory exposures should immediately bring them to the attention of Yale EHS and the lab supervisor or Principal Investigator.

1.7 MEDICAL CONSULTATION & EXAMINATION

The University provides personnel who work with hazardous chemicals an opportunity to receive medical attention through the Employee Health or Student Health programs, including any follow-up examinations which the examining PLHCP determines to be necessary, whenever personnel:

- develop signs or symptoms associated with excessive exposure to a hazardous chemical used in their laboratory;
- are exposed routinely above the action level (or in the absence of an action level, the applicable OSHA workplace 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 emergency room at Yale-New Haven Hospital. An ambulance can be obtained by dialing 911 from any phone. Follow-up medical examination/consultation visits will be handled by the Acute Care PLHCP at Yale Health or the facility they designate. The appropriate facility to visit can be identified by calling Yale Health Acute Care Department at 203-432-0123. The appropriate PLHCP at the Yale Health Center will administer non-urgent medical examinations and consultations, as well as medical surveillance.

1.7.1 Medical and Workplace Consultations - Reproductive Toxins

Exposure to certain chemicals may adversely affect fertility and may affect the developing fetus during pregnancy. Therefore, anyone working with reproductive toxins or teratogenic agents planning to conceive a child or who is pregnant should consult their Principal Investigator or supervisor, 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, with the individual and the Principal Investigator or laboratory supervisor, as appropriate, adjust work practices to minimize risk. The Employee Health or Student Health PLHCP can discuss the potential risks of exposure as they apply to each situation. Information on reproductive and developmental hazards, including lists of materials suspected of causing such effects, is available in the "*Reproductive and Developmental Hazards Safety Guidelines*" at ehs.yale.edu.

1.8 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). Exposure assessments refer to the quantitative evaluation of hazardous materials, i.e., environmental (workplace) monitoring or measurement of toxic substances or harmful physical agents. Occupational medical records include medical questionnaires, results of pre-employment, pre-assignment, periodic, or episodic medical examinations, laboratory tests taken to establish a baseline or detect occupational illness, and associated medical opinions, diagnoses, recommendations, and treatments, as applicable.

Individuals may obtain copies of or read their reports by submitting a written request to EHS (exposure assessment records) or the Employee Health Department (occupational medical records).

1.9 LABORATORY SAFETY INSPECTION PROGRAM

The designated Safety Advisor from EHS conducts, at a minimum, annual safety inspections of all University laboratories that handle or store hazardous materials. As part of these inspections, the 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 required for laboratories handling higher-risk materials. Inspection times are arranged in advance with Principal Investigators (PI)/Director/Supervisor and/or lab managers, and PIs/Directors/Managers receive an electronic report of the inspection results, along with recommendations and deadlines for improvements, through the Yale EHS Integrator program. The PI/Director/Manager, or their designee, must respond to each issue noted in 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.

1.10 PROTOCOL REVIEW

Under certain circumstances, a specific chemical substance and the associated laboratory operation, procedure, or activity may be deemed sufficiently hazardous to require prior EHS approval before work 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 3.0 HEALTH AND SAFETY INFORMATION FOR WORK WITH CHEMICALS OF SPECIFIC HAZARD CLASS, including larger volumes and scaling up of experiments.

The chemicals 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, laboratory personnel must provide detailed information on the protocol, including the specific chemical(s), proposed handling, storage, and disposal procedures. Once laboratory personnel submit the registration, it is routed to EHS and the Principal Investigator/Director/Manager 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. Laboratory Personnel handling these materials receive information specific to the chemical's hazards 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 is not familiar with and need special guidance, or for hazardous chemicals being used in a manner outside of the procedures outlined in this plan, Yale EHS will need to review the proposed activity/procedure and provide approval prior to work beginning. Depending on the procedure and materials, Laboratory Personnel may be asked to complete the chemical registration using EHS Integrator or submit a protocol, including all relevant safety information, to EHS for review.

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 SDS 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 storing, transporting, and disposing 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 any additional PPE requirements for lab tasks or activities. This assessment must be completed in EHS Integrator; the tool can be found at Laboratory PPE Assessment. At a minimum, safety glasses, a lab coat, exam-style nitrile gloves, clothing that covers the legs, and closed-toe, solid-top shoes are required when working with hazardous materials in the laboratory. Inspect PPE and clothing for integrity and proper function before use.
- Pull back and secure long hair; long beards should also be contained.
- Avoid working alone in the laboratory whenever possible. If working alone is necessary (e.g., after normal business hours), you must inform another individual of your location, the nature of your work, and your expected duration in the laboratory. Arrange for periodic check-ins. Working alone is strictly prohibited when:
    - Handling highly hazardous chemicals
    - Performing high-hazard operations
    - Using materials or equipment that are specifically prohibited for lone work.

  When planning work involving highly hazardous chemicals, schedule these activities during normal working hours and ensure that other trained personnel are present in the laboratory. Notify other laboratory members before beginning such work. Refer to the *"Policy on Working Alone in Laboratories"* for University-wide requirements, definitions, and a list of materials/equipment that may not be used while working alone.
- Complete required EHS training prior to beginning work. Successful completion of Yale University's "*Laboratory Safety Program*" in Workday Learning 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 involving volatile, toxic, or malodorous substances should be performed only 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 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.
- For laboratory work involving hazardous substances that will be continuous in your absence or overnight, you must post the "Unattended Operations" form on either the fume hood or the lab door, clearly displaying your name, contact information, and the hazardous materials in use. Please refer to APPENDIX E UNATTENDED OPERATIONS POSTING or visit ehs.yale.edu for the form.

2.1.2 Personal Hygiene

- Remove contaminated clothing and gloves before leaving the 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 waft, smell, inhale, or taste a hazardous chemical. Wash thoroughly with soap and water after handling any chemical.
- Smoking, vaping, drinking, eating, and the application of cosmetics are forbidden in laboratories where hazardous chemicals are used. See APPENDIX B YALE UNIVERSITY POLICY ON EATING, DRINKING, AND SMOKING IN LABORATORIES.
- Never pipette by mouth. Use a pipette bulb or another mechanical pipette 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 for storage.
- 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, electrical panels, showers, eyewashes, fire extinguishers, and exits should never be blocked.
- Waste must be stored in appropriate containers and be properly labeled. All hazardous waste containers must be labeled with the full chemical names of the contents and the words "hazardous waste". Ensure these containers are tightly capped when waste is not being added. Latching funnels are acceptable for use if they have a latching lid to prevent spills or vapor release.

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 can collapse violently, either spontaneously (if cracked or weakened) or from an accidental blow. Use extra care with Dewar flasks and other evacuated glassware; shield or wrap them with safety netting to contain chemicals or fragments in the event of an implosion.

2.2 RISK ASSESSMENT AND REVIEW OF SAFETY PROCEDURES

Effective hazard control begins with thoughtful experimental design. Prior to conducting laboratory work, laboratory personnel must evaluate the hazards associated with the chemicals, equipment, and procedures involved and implement appropriate control measures.

A laboratory risk assessment should include:

1. Identification of materials and quantities to be used
2. Evaluation of chemical and physical hazards
3. Determination of appropriate engineering controls
4. Selection of required personal protective equipment (PPE)
5. Planning for emergency response and spill management
6. Reassessment of hazards when procedures change

See APPENDIX F CHEMICAL HAZARD RISK ASSESSMENT FORM for a sample that can assist in conducting a successful risk assessment.

Risk assessments must be revisited whenever:

- New chemicals or procedures are introduced
- Experimental quantities are significantly increased
- Equipment or process changes occur
- Unexpected reactions or byproducts are observed
- Engineering controls malfunction
- Signs or symptoms of potential exposure arise

Scaling up experiments or modifying procedures may introduce new hazards, including increased heat generation, pressure buildup, or the formation of toxic byproducts. Laboratory Personnel must reassess hazards and confirm that existing controls remain adequate before proceeding.

The occurrence of any of these conditions should prompt Laboratory Personnel to pause, evaluate the safety implications of the changes or results, make adjustments as necessary, and proceed cautiously. If needed, contact EHS 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 implemented, or while such controls are being established. These devices are considered less effective than other controls because they rely heavily on each person's work practices and training. 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, less hazardous equipment, or less hazardous process
- Scaling down the size of the 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 (ANSI Z87 safety glasses or goggles at a minimum), clothing that covers the legs, and closed-toe, solid-top shoes are required whenever handling hazardous chemicals in Yale laboratories. Additional personal protective equipment, such as face shields, 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/Directors/Managers and supervisors must provide appropriate personal protective equipment to Laboatory Personnel. Refer to the Laboratory PPE Hazard Assessment" in APPENDIX G SELECTION AND USE OF PERSONAL PROTECTIVE EQUIPMENT

2.3.1 Standard Laboratory Clothing – Appropriate Attire

Even when there is no immediate risk of skin contact with a hazardous chemical, it is still important to wear clothing that minimizes exposed skin when in the laboratory. Laboratory Personnel must wear safety 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, exam-style gloves, and a laboratory coat (or its equivalent in certain circumstances – apron, barrier gown, etc.) are required to be worn whenever working with hazardous materials. Prescription glasses may be worn only when working with hazardous materials if they are prescription **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 thoroughly washed.

2.3.2 Additional Personal Protective Equipment

Additional PPE may be required for certain procedures or when handling specific substances or operations, such as when larger quantities of corrosives, oxidizing agents, or organic solvents are present. 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 PPE. 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), assess the risk of exposing non-laboratory personnel during laundering. Wear disposable garments if others may be exposed to risk during laundering. Lab coats must be laundered through an approved laundry service or facility; please see the University Buying Guide.

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 based on the materials being handled, the specific hazard involved, and the operation's requirements. Before each use, gloves should be checked for integrity. 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 provide better chemical protection than latex or vinyl gloves. 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 because they are thin, it may be advisable to wear double nitrile gloves if contact is possible. Thicker utility-style reusable gloves should be worn over thin exam-style gloves if there is a high probability of contact with hazardous chemicals. Reusable gloves should be washed before removal and replaced periodically, depending on use frequency and the substances handled. The following table offers a general guide to glove selection.

Glove Material	Intended Use	Advantages	Disadvantages
Latex exam style	Incidental Contact	• Good for biological and water-based materials • User acceptability	• Poor for organic solvents • Hard to detect puncture holes

			• Latex allergy issues
Nitrile - exam style	Incidental Contact	▪ Good for solvents, oils, greases, some acids, and bases ▪ Clear indication of tears and breaks ▪ User acceptability	• May be slightly more expensive than latex
Nitrile - utility style	Extended Contact	▪ Good for solvents, oils, greases, some acids, and bases ▪ Can be washed and reused	• Not effective for halogenated and aromatic hydrocarbons
Neoprene – utility style	Extended contact	▪ Good for acids, bases, alcohols, fuels, peroxides, hydrocarbons, and phenols	• Poor for halogenated and aromatic hydrocarbons
Butyl rubber - utility style	Extended contact	▪ Good for ketones and esters	▪ High cost
Silver Shield - Teflon	Extended contact	▪ Good for most chemicals	▪ Lack of dexterity ▪ Very expensive

Contact your EHS Safety Advisor for assistance with PPE selection or information.

2.3.4 Eye Protection

Eye protection is required for all people 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 a 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 splashes. 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 be best controlled with 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 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 through engineering controls (e.g., ventilation) is always the preferred method. As with other PPE, respiratory protection relies heavily on the fit of the respirator, work practices, and training to be effective.

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

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 involves completing a medical surveillance questionnaire, which is evaluated by the Employee Health Physician or Other Licensed Health Care Professional (PLHCP). The Employee Health PLHCP 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 EHS.

Under some circumstances, laboratory personnel may wish to use respiratory protection equipment for their own comfort or sense of well-being, even when there is no recognized hazard or overexposure. Respirator use in these circumstances would be considered "voluntary". For voluntary users, respirator fit testing is not required. Voluntary users of filtering facepiece respirators (N95, N100) are also not required to undergo medical clearances. Voluntary users of all other respirators are required to complete the medical clearance questionnaire and obtain medical clearance. Anyone wearing a respirator under the voluntary use provision must complete the Workday Learning course *Voluntary Use of Respirators*. See Yale University's Respiratory Protection Program for more information about respirator use requirements.

2.3.5 Laboratory Safety Equipment

2.3.5.1 Fume Hoods

Chemical fume hoods are the primary engineering control for reducing inhalation exposure to hazardous vapors, gases, and particulates. When used properly, they protect laboratory personnel by capturing and exhausting airborne contaminants away from the breathing zone. Fume hoods can also be used to isolate apparatus or chemicals that may present physical hazards to Laboratory Personnel. The closed sash on a hood serves as a barrier against fire, flying objects, and chemical splashes or spatter.

Standard fume hoods are typically certified to operate at approximately 100 feet per minute (fpm) (±20%) at the normal operating sash height. High-performance fume hoods are designed to operate safely at lower face velocities while maintaining effective containment and are certified in accordance with Yale EHS performance criteria. All laboratory fume hoods are inspected and certified annually under the Yale EHS fume hood certification program.

When using a chemical fume hood:

- Conduct work at least six inches inside the hood
- Keep the sash at or below the indicated operating height
- Avoid blocking air baffles or disrupting airflow
- Elevate large equipment to maintain airflow beneath the apparatus
- Minimize storage inside the hood
- Follow the instructions on the "Safe Use of Laboratory Fume Hoods" sticker posted on the hoods.

All operations involving volatile, toxic, reactive, or malodorous chemicals must be conducted in a functioning chemical fume hood or other approved local exhaust ventilation system. Contact EHS with any questions or concerns regarding engineering controls for specific operations.

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 various factors, including sash position, motion sensors, and room light switches, often in conjunction with the time of day.

Many constant air volume systems are on hoods that have a bypass design over the sash. These use more energy than other hood systems because they operate on the principle of a constant air volume 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 to keep face velocity constant while exhaust volume decreases as the sash is lowered. The sashes on these hoods should be kept as low as possible when not in use. Some of these systems are supplemented with motion sensors that reduce flow rates when no one is actively working at the hood.

2.3.5.2 Filtering (Ductless) Fume Hoods

Filtering fume hoods, or ductless chemical fume hoods, recirculate air back to the laboratory after it passes through a filter. They are offered by a variety of manufacturers. The primary safety concern with filtering fume hoods is the risk that vapors may not be fully removed by the filter media and may be recirculated back into the laboratory. **These systems must be used with extreme caution. Yale EHS must be consulted before purchasing or using ductless fume hood systems for chemical exposure control. These hoods may not be purchased nor installed without prior approval from Yale EHS.**

Applications where these units might be appropriate include particulate control, low-hazard chemical control, and nuisance-odor control. **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 may damage 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 for supplies, carts, and related items. There should be at least 32 inches of clear space around the shower and 6 feet 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. Submit a work request to Facilities Operations if the eyewash is not functioning properly.
- Shower locations should be checked routinely by laboratory personnel to ensure that access is not restricted and that the start chain or lever is within reach.
- The testing program for safety showers and eyewashes is managed by EHS. They are tested annually to ensure proper operation and sufficient flow rates. Additional testing may be required for DPH-registered laboratories. For more information, contact your Safety Advisor.

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, Manager, Director, 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 for handling 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, require special facilities/handling or are of special interest for reporting reasons 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 and "bump" protection. If several bottles must be moved at once, they should be transported on a small cart with a substantial rim to prevent slippage. Where available, a freight elevator should be used to transport chemicals between floors. The stockrooms will not allow purchases of hazardous liquids unless a chemical carrier is available to return the containers 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 and 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, some chemicals may fall into multiple hazard categories, and the label and SDS 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 for chemical storage by compatibility are 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 may be stored outside rated flammable storage cabinets or safety cans in any laboratory.

Flammable chemicals requiring refrigeration may only be stored in refrigerators and freezers specifically designed for flammable storage.

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

Hazardous chemicals should generally 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 cannot 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 contents' identity 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 a chemical's susceptibility to hazardous decomposition. The label and SDS will indicate if a chemical is unstable.

See SECTION 3.2 HIGHLY REACTIVE CHEMICALS & 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 chemicals form peroxides that are violently explosive in concentrated solution or as solids; therefore, they should never be evaporated to dryness. Others are unsaturated polymerizable compounds that 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 must be dated upon receipt and again 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

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 occurs. This includes keeping the necessary equipment (e.g., spill kits and PPE) in the lab to respond to minor spills, learning how to safely clean up minor spills of regularly used chemicals, and knowing what to do if there is a leak from a compressed gas cylinder or from piped gases.

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 EHS is equipped to handle most spills that may occur on the University campus. If there is any doubt about how to proceed, request assistance from EHS.

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

- Aromatic amines
- Bromine
- Carbon disulfide
- Cyanides
- Hydrazine
- Organic Halides
- Nitriles
- 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 if they are comfortable doing so, fully understand the hazards of the spilled material, and know the methods to protect themselves. They should follow the procedure below for cleaning up:

- Review the SDS section on spill clean-up
- Alert people in the immediate area and restrict access to the spill location.
- Avoid vapor or dust from spills. If dry/powder material is spilled, minimize air disturbances and drafts. However, if a 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 SDS for additional information. Evaluate hazard(s) and address personal contamination/injury. Summon any additional emergency services needed.

- To clean up a minor chemical spill, wear PPE appropriate to the hazard – if respiratory protection is needed, the incident is NOT minor. Refer to the Laboratory Hazard Assessment Tool (LHAT).
- Use an appropriate kit to absorb or neutralize spilled material. Work from the perimeter inwards. Collect the residue with a scoop or dustpan, place it in a heavy plastic bag or another receptacle, affix a hazardous waste label describing the contents, and contact Yale EHS for waste pickup.
- Clean spill area with soap and water.
- If the floor finish has been damaged, contact Custodial Services.

If there are any concerns or questions about the ability to safely clean the spill, EHS should be contacted.

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 the spill to keep the substance from volatilizing.
- Close doors to the affected area.
- Call **the 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

Contact EHS if you have a mercury spill that exceeds the amount in a standard laboratory thermometer, or if you require assistance with cleaning up any amount of spilled mercury.
Follow these steps to clean up a small mercury spill:

- Do not use a domestic or commercial vacuum cleaner.
- 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 EHS for disposal information.
- Contact EHS to determine if it is necessary to monitor mercury vapor levels in the room after clean-up.

2.5.5 Alkali Metal Spills

- Smother with powdered graphite, sodium carbonate, or calcium carbonate or "Met-L-X", call EHS 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 people and remove them from exposure.
  - Alert people in the laboratory to evacuate.
  - Close doors to the affected area.
  - Call the **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 the affected area.
  - Call the **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 the chemical involved and provide to the appropriate emergency responder and health care provider.

Some chemicals (e.g., phenol, aniline) are rapidly absorbed 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 are 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 the 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 PLHCP 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 by smoke, chemical vapors, or fumes should be moved 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 the exposed person to uncontaminated air and treat for shock (sit or lie down, cover to keep warm, remain with the 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 suspects 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 of 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. Yale EHS currently purchases and distributes the gel free-of-charge to all HF user locations. Please contact your Safety Advisor or EHS 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 ensure thorough flushing.
- 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.

2.6.9 Phenol

Phenol or phenol-containing products (e.g., Trizol or QIAzol) are toxic by inhalation, skin absorption, and ingestion. They are corrosive, causing skin burns and eye damage. Phenol is readily absorbed through the skin and can cause systemic effects. It has an anesthetic effect, and therefore, the burn may not be immediately noticeable due to numbness. PEG 300/400 is an effective treatment for skin contact with phenol. Every laboratory and location where phenol is used or stored should have a bottle of PEG 300/400 readily available. Please contact your Safety Advisor or EHS if you work with phenol and need PEG 300/400.

2.6.9.1 Skin Exposure to Phenol/Phenol-containing products

- Remove contaminated clothing.
- Swab area repeatedly with PEG 300/400, changing out with fresh swabs frequently.
- Continue PEG swabbing until EMS arrives or odor is no longer detectable.
- Use the emergency shower for 15 minutes if no PEG is available.

2.6.9.2 Eye Exposures to Phenol/Phenol-containing products

- 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.
- Contact 911 and inform the dispatcher that eye exposure involves phenol.
- Continue to rinse in eyewash until EMS arrives.

2.6.9.3 Inhalation Exposures to Phenol/Phenol-containing products

- Move the 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 phenol/

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 in evacuating;
    - 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 may know is essential to the safety of emergency responders.

If the fire alarms are ringing in your building:

- You must evacuate the building and stay out until you are 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 the emergency gas shut-off for the affected area;
- Evacuate the area.

2.8 CHEMICAL WASTE DISPOSAL PROGRAM

Laboratory chemical waste must be handled in accordance with the University's policy and management guidelines outlined in the Management of Hazardous Waste Procedure, available at ehs.yale.edu. The University's waste management practices are designed to ensure a safe and healthy environment for laboratory personnel and the surrounding community, without adversely affecting the environment. This is accomplished by regularly removing chemical waste from University facilities and disposing of it in compliance with local, state, and federal regulations. The manual provides laboratory personnel with specific guidance on identifying, handling, collecting, segregating, storing, tagging, and disposing 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:

Specific Chemicals	Class/Group of Chemicals
Acrolein	Acutely Toxic Materials
Aqua Regia	Carcinogens
Hydrofluoric Acid	Corrosives
Isoflurane	Flammable Liquids
Osmium Tetroxide	Organic Peroxides and Peroxide-Forming Compounds
Phenol	Particularly Hazardous Substances
Piranha	Potentially Explosive and Explosive Compounds
Potassium or Sodium Cyanide	Pyrophoric and Reactive Compounds
Sodium Azide	Strong Oxidizers
Tetramethylammonium Hydroxide	Corrosives
(Trimethylsilyl) Diazomethane	Flammable liquids

3.1 FLAMMABLE LIQUIDS

3.1.1 General Information

Flammable liquids are among the most common 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. 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 a fire from starting. Flammable liquids may form flammable mixtures in open or closed containers or spaces (such as refrigerators) when heated or when leaks or spills occur in the laboratory.

Strategies for preventing the ignition of flammable vapors include removing all sources of ignition or maintaining the concentration below the lower flammability limit by using local exhaust ventilation, such as a fume hood. The former strategy is more difficult due to the numerous ignition sources in laboratories, including open flames, hot surfaces, operating 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 may result that can flash back to the vapor source.

The risk of fire and explosion posed by flammable liquids can usually be eliminated or minimized by strict adherence to safe handling, dispensing, and storage 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 when 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 other local exhaust ventilation. When dispensing flammable solvents into small storage containers, use metal or plastic containers or safety cans and avoid glass containers. If splash risk is high, wear a face shield in addition to goggles.

Make sure that metal surfaces or containers through which flammable substances are flowing are properly grounded to discharge 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 are placed in ovens, ensure they are appropriately designed for flammable liquids (no internal ignition sources and mechanically vented). Make sure the solvent's autoignition temperature 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 that are inherently unstable and susceptible to rapid decomposition, as well as chemicals that, 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 with temperature, if heat evolved from a reaction is not dissipated, the reaction can accelerate out of control, resulting 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 exhibit unusual stability issues, making them among the most hazardous substances commonly handled in 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, especially after exposure to air (once opened). Peroxide-forming substances include: aldehydes, cyclic ethers, compounds containing benzylic hydrogen atoms, compounds containing the allylic structure (including most alkenes), and vinyl and vinylidine compounds.

3.2.2 Special Handling Procedures for Highly Reactive Compounds

Before working with highly reactive materials or high-energy oxidizers, review the available 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 made available for work involving these materials.

When working with highly reactive compounds and high-energy oxidizers, always wear the following PPE: lab coats, chemical-resistant gloves, and safety glasses/goggles. Long pants or clothing that covers the legs 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, depending on the scale and nature of the material and the reaction. Refer to the Laboratory Hazard Assessment Tool (LHAT) 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, with consideration of reaction vessel size and cooling, heating, stirring, and equilibration rates; a separate SOP should be conducted for all scale-ups. A new risk assessment is required for any scale-up of procedures involving highly reactive materials.

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 involving highly reactive and explosive chemicals should be performed during the normal workday 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 consider when assessing the hood's adequacy include its size relative to the reaction and required equipment, and the ability to fully close the sash. Keep the sash between you and the highly reactive material and use a blast shield as needed.

Handle highly reactive chemicals away from 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 that 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, dark location. If you use a refrigerator, make sure it is rated for storing flammable substances. Store light-sensitive compounds in 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 must include the date the container was received and the date it was 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 condense in the ventilation system, leaving highly reactive perchlorate crystals that can pose a serious fire and explosion hazard. Perchlorates can form if 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 EHS if you plan to heat perchloric acid, use highly concentrated solutions, 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, 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 these chemicals are flagged as Restricted and are routed to EHS for approval. Anyone using pyrophoric compounds must complete the "*Pyrophoric Safety Program*" in Workday Learning prior to beginning work.

Basic rules for working with pyrophoric chemicals at Yale University are as follows:

Clothing and PPE 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 they can be worn over exam-style nitrile gloves. Flame-resistant lab coats and flight gloves are available through Workday. The Laboratory Hazard Assessment Tool (LHAT) should be used to determine the appropriate PPE requirements. Contact EHS for more information.

Look to use less reactive materials 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 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, with consideration of reaction vessel size and cooling, heating, stirring, and equilibration rates. A new risk assessment is required for any scale-up of procedures involving pyrophoric chemicals.

Only work with pyrophoric chemicals in areas with 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 to work with organolithium compounds must also follow the additional requirements outlined below.

- Complete the Workday Learning Training in the "*Pyrophoric Safety Program*."
- Dispose of containers 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 or blast 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 physical and potential chemical hazards, depending on the 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 rapidly if leaks develop at the regulator or in the piping system, posing a risk of 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 the 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, a 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 PPE 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 to identify 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 so the cylinder valve is always accessible. The main cylinder valve should be closed as soon as the gas flow is no longer needed. Do not store gas cylinders with the regulator under pressure.

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 that could affect the integrity of the system. Always use a leak-check solution 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.

In general, avoid purchasing lecture bottles. These cylinders are not returnable, and disposing of them is extremely difficult and costly. 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 EHS.

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 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 dangerous to work with. 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. They require EHS approval prior to purchase and must be registered in the Yale chemical registration program.

Toxic, corrosive, and pyrophoric gases must be stored and used under local exhaust ventilation, either in an exhausted gas cabinet or in another EHS-approved exhausted enclosure. Flammable gases may also need to be stored in a vented gas cabinet. Be sure to check with the Office of Fire Code Compliance (OFCC) and EHS prior to initial purchase of flammable gas cylinders or when increasing the number of flammable gas cylinders.

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 pose both health and physical hazards. As a health hazard, corrosive substances can rapidly destroy or alter living tissue by chemical action at the site of contact. Symptoms of exposure to corrosive vapor or mist include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea, and vomiting. For eyes, symptoms include pain, tearing, and blurred or lost vision. For skin, symptoms may include reddening, pain, inflammation, blistering, and burns. Corrosive substances present a physical hazard due to their ability to corrode materials upon contact and their potential to react vigorously with other chemicals. It is important to review information on the materials they corrode, their reactivity with other substances, and their health effects.

If you suspect you may have been exposed to a corrosive chemical, flush the exposed area with water for at least 15 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, causing painful burns. 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 requires specific emergency procedures and an antidote gel in all locations where HF is used or stored. See SECTION 2.6.8 Hydrogen Fluoride/Hydrofluoric Acid 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, allowing the material to penetrate 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 when these substances are mixed with water, mixing should always be done by adding the agent to water, not the reverse, to avoid violent reactions and splattering. 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, as described above, powerful oxidizing agents such as concentrated hydrogen peroxide (>30%), bromine, chlorine, perchloric acid, and chromic acid pose a fire hazard when they come into 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 the recommended operating procedures for highly reactive compounds (see SECTION 3.2 HIGHLY REACTIVE CHEMICALS & HIGH ENERGY OXIDIZERS).

3.4.2 Special Handling Procedures

When working with corrosive chemicals, wear appropriate gloves, safety glasses or goggles, a long-sleeved lab coat, and closed-toe, solid top shoes. Handling bulk quantities of these chemicals requires the use of rubber aprons, face shields, and goggles, and utility-grade gloves. Refer to the Laboratory Hazard Assessment Tool for the required PPE for your operation.

Corrosive chemicals should be handled only in a chemical fume hood. Use plastic trays for containment when handling in bulk (> 1 liter) and when there is a risk 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 unavailable, store them under fume hoods or on low shelves in impervious trays to physically separate them from other chemical groups. Do not store volatile, corrosive chemicals such as hydrochloric acid in a flammable cabinet, as their vapors will corrode the cabinet. Keep containers not in use in storage areas and off bench tops whenever 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 with high acute and chronic toxicity, including 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 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/Director/Manager 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 a long-sleeved laboratory coat. Protect your eyes with safety goggles or glasses. If the procedure involving these chemicals has the potential to splash, 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 laundering. Refer to the Laboratory Hazard Assessment Tool (LHAT) to determine the appropriate PPE for your operation.

All PPE should be removed before leaving the designated area. If necessary, decontaminate PPE, and if disposable, place it in a plastic bag and secure it 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 containment device, such as a glove box.

Analytical instruments or other laboratory equipment that generate vapors and/or aerosols during operation should be locally exhausted or vented into 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 chemicals listed as chemical warfare agents 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, a portion of a laboratory, or a storage or containment device, such as a laboratory fume hood. Others working in the area should be informed of the specific hazards associated with these substances and the appropriate precautions needed to prevent exposure. All designated areas should be posted with a sign which reads:

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

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

Work surfaces on which these substances will be handled should be easy to decontaminate or protected from contamination using plastic trays or plastic-backed paper. Refer to the SDS or contact EHS 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 child-bearing age should be informed of any known reproductive toxins used in the laboratory. Lab personnel who are pregnant, or planning to become pregnant, and who are working with potential reproductive toxins that might affect the fetus, should contact EHS to evaluate their exposure. The lab personnel should also inform the Employee and Student Health PLHCP, and their personal PLHCP, of the specific substance being used, as necessary. The Chemical Hygiene Officer can assess potential exposures and, if necessary, work with the principal investigator or laboratory supervisor to adjust work practices to minimize risk.

Highly toxic chemicals are flagged as restricted and routed to EHS for approval. The list of restricted chemicals, including highly toxic ones, is available at http://ehs.yale.edu/forms-tools/chemicals-requiring-ehs-pre-approval. An inventory of these chemicals is 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 CARCINOGENS AND REPRODUCTIVE TOXINS. 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

Note: As of July 28, 2023, Congress allowed the statutory authority for the Chemical Facility Anti-Terrorism Standards (CFATS) program (6 CFR Part 27) to expire. Yale EHS continues to approve and track each of these chemicals and the handling procedures specified below should continue to be followed.

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; their purchase is flagged and routed to EHS for approval, and a container-level inventory 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 exhibit one or more hazardous characteristics outlined previously, e.g., flammability, acute toxicity, 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 with increasing exposure. All chemicals exhibit toxic effects at sufficiently high doses. The toxic potency of a chemical is thus ultimately defined by the dose (amount) that produces 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 inhalation exposure. These limits are normally expressed in terms of either parts per million (PPM) or milligrams per cubic meter (mg/m^3) concentration in air. If a significant (or systemic) exposure to 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 exposure over 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 occurs at a location distant from the body's initial point of contact and presupposes that absorption has occurred. 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 because 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 that normally has no toxic effect 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 lifestyle*** 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

A **gas** is a substance that is in the gaseous state at room temperature and pressure.

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

When assessing the toxicity of gases and vapors, solubility is a key factor. Highly soluble materials, like ammonia, irritate the upper respiratory tract. On the other hand, relatively insoluble materials, such as nitrogen dioxide, penetrate deeply into the lungs. Fat-soluble substances, such as pesticides, tend to have longer residence times in the body and are 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 determines whether it will be deposited in the respiratory system and where. Particles above 10 micrometers tend to deposit in the nose and other areas of the upper respiratory tract. Particles smaller than 10 micrometers enter the lung and are deposited there. Very small particles (<0.2 micrometers) are generally not deposited but exhaled.

4.1.7 Physiological Classifications

Irritants are materials that cause inflammation of the mucous membranes with which they come in contact. Tissue inflammation results from exposure to concentrations far below those needed to cause corrosion. Irritants can also alter 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 liver damage. Examples: Carbon tetrachloride, Tetrachloroethane, Nitrosamines.

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

Neurotoxic agents damage the nervous system. The nervous system is especially sensitive to organometallic compounds and certain sulfide compounds. Examples include:

- Trialkyl tin compounds
- Methyl mercury
- Organic phosphorus insecticides
- Manganese
- Tetraethyl lead
- Carbon disulfide
- Thallium

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 to 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 that induces cancer or increases its incidence. Substances and mixtures that have induced benign and malignant tumors in well-performed experimental studies on animals are also considered to be presumed or suspected human carcinogens unless there is strong evidence that the mechanism of tumor formation is not relevant for humans.
A chemical is considered a carcinogen or potential carcinogen if it is listed in any of the following publications:

- National Toxicology Program, Annual Report on Carcinogens (latest edition) – listed under the category of "known to be carcinogens"
- International Agency for Research on Cancer, Monographs (latest edition) – listed as either Group 1, Group 2A or Group 2B
- Regulated by OSHA as a carcinogen under 29 CFR 1910 Subpart Z, Toxic and Hazardous Substances

Known human carcinogens include:

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

A **mutagen** causes heritable changes (mutations) in the genetic material (DNA) of exposed cells. If germ cells are involved, the effect may be inherited and become part of the genetic pool passed on to future generations. Ethidium bromide is an example of a mutagen.

A **teratogen** (embryotoxic or fetotoxic agent) is an agent that 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 that can cause an allergic reaction in normal tissue after repeated exposure. The reaction may range from a mild rash (allergic dermatitis) to 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 that may occur from chemical exposure. Signs and symptoms of these effects, along with examples of chemicals found to cause them, are listed below.

Toxins	Target organ effect	Signs and symptoms	Example chemicals
Hepatotoxins	Causes liver damage	Jaundice; liver enlargement	Nitrosamines, chloroform, toluene, perchloro-ethylene, cresol, dimethyl sulfate, carbon tetrachloride
Nephrotoxins	Causes kidney damage	Edema; proteinuria	Halogenated hydrocarbons, uranium, chloroform, mercury, dimethyl sulfate
Neurotoxins	Affects the nervous system	Narcosis; behavior changes; decreased muscle coordination	Mercury, carbon disulfide, benzene, carbon tetrachloride, lead, nitrobenzene
Hematopoietic toxins	Decreases blood function	Cyanosis; loss of consciousness	Carbon monoxide, cyanides, nitrobenzene, aniline, arsenic, benzene, toluene
Pulmonary toxins	Irritates or damages the lungs	Cough; tightness in chest, shortness of breath, pulmonary edema	Silica, asbestos, ozone, hydrogen sulfide, chromium, nickel, alcohols
Reproductive toxins	Affects the reproductive system	Birth defects; sterility	Lead, 2-ethoxyethanol, dibromodichloropropane, toluene
Skin hazards	Affects 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 over a working lifetime without 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 workday. 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 at any time during a 15-minute period during an 8-hour workday. 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 EHS office has a complete listing of published TLVs and PELs, as well as other information on chemical toxicology. If you would like to conduct a thorough review of a particular compound, contact EHS. The references available upon request to the EHS office are listed in APPENDIX C LABORATORY SAFETY REFERENCES.

SECTION 5.0 GLOSSARY OF TERMS

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

ACUTE - Short duration, rapidly changing conditions.

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

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

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

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

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

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

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

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

ºC - 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 $140^{O}F$. 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.

LABORATORY PERSONNEL - Laboratory personnel include faculty, staff, students, trainees, clinical laboratory staff, conservation professionals, visiting scholars, contractors, and any other individuals who work in Yale laboratories where hazardous chemicals are used or stored.

LEL - See LOWER EXPLOSIVE LIMIT.

LETHAL CONCENTRATION$_{50}$ (LC_{50}) - 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 the toxicity of a substance.

LETHAL DOSE$_{50}$ (LD_{50}) - 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 the 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/m^3) - 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.

NON-PRODUCTION LABORATORY – a laboratory space that is used for research, teaching, clinical, or academic purposes where chemicals are handled on a laboratory scale and not for commercial manufacturing or large-scale production.

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, is 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 be a time-weighted average (TWA) exposure limit (8-hour), a 15-minute short-term exposure limit (STEL), or a ceiling (C). PELs 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 workday), 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 1 PPM and the UEL is 5 PPM, then the explosive range of the chemical is 1 PPM to 5 PPM. (see also LEL).

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

APPENDIX A SUMMARY OF OSHA'S LABORATORY STANDARD

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

The Laboratory Standard requires laboratories to develop procedures to reduce or minimize occupational exposure to hazardous chemicals in the laboratory environment.

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 Standard is primarily a performance-oriented standard, allowing individual laboratories to tailor their approaches to meeting the standard's requirements to their circumstances.

A copy of this standard is readily available 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 the entire laboratory, not just to areas where hazardous materials are used. This prohibition applies to 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 involving 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 that will close, and in which hazardous materials are never used or stored.[2] On a case-by-case basis, exceptions to this restriction may be granted for covered beverages in interior office spaces that do not meet all of these requirements, upon a formal request for review by EHS. 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 there.

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

[2] In Biosafety 3 laboratories, the prohibition applies to all areas, including interior offices and similar spaces, even if they are separated by such barriers.

APPENDIX C LABORATORY SAFETY REFERENCES

Available upon request from Environmental Health and Safety:

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.

Budavari (ed). *The Merck Index: An Encyclopedia of Chemical Drugs and Biologicals.* Merck Research Laboratories, New Jersey. 1996.

Clayton, G.D. and Clayton, F.L. (ed.). *Patty's Industrial Hygiene ad Toxicology.* General Principles, Vol. I through III. Wiley Interscience, New York. 1982.

Furr, A. K. (ed.). *CRC Handbook of Laboratory Safety, 5th ed.* CRC Press, Boca Raton, Florida. 2000.

Greenberg, M. *Occupational, Industrial, and Environmental Toxicology, 2nd edition.* Mosby, Inc., Pennsylvania. 2003.

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.*

29 CFR 1910 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/Email: ______________________________
Date: ______________________________

CHEMICAL NAME______________________
SYNONYMS______________________
CHEMICAL STRUCTURE:

EMPIRICAL STRUCTURE______________
MOLECULAR WEIGHT______________
HEALTH REMARKS *(identify known adverse effects)*______________________
____

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 products 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.

APPENDIX E UNATTENDED OPERATIONS POSTING

Instructions: *Complete this form and attach it to the fume hood whenever a process is left unattended. Assume the worst-case scenario when determining which hazards apply.*

ATTENTION

Emergency Information - Unattended Operations

Contact Name:____

Contact Cell 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, Please Shut off:
(circle all that apply)

Electricity

Vacuum

Gas Source

Water Source

Hot Plate/Ignition Sources

APPENDIX F CHEMICAL HAZARD RISK ASSESSMENT FORM

Completing this document will help you to identify the risks associated with your laboratory work.

Title of Experiment or Procedure: ____

Initial & Additional Review Date(s): ____

Brief Description of Experiment or Procedure *(include reaction conditions such as temperature or pressure, etc., 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 *e.g. powder, vapor, 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 a likelihood of copious amounts of gas being released or thermal runaway? If the 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 with a less hazardous substance?	Y/N
What could happen if there were a catastrophic failure of the apparatus?	
In the event of an accident, who might be exposed?	

Control measures to be used:

Containment

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

Personal Protective Equipment

- ☐ Lab coat (type):______________________
- ☐ Chemical apron
- ☐ Gloves (type): ______________________
- ☐ Eye protection (type):_________________
- ☐ Respirator* (type): ___________________
  *Note: Contact EHS before wearing a respirator
- ☐ Other (specify): _____________________

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 assessment must be completed online at* https://ehsis.yale.edu/EHSIntegrator/Survey/LabPPE.** All Activities/Jobs/tasks that apply to your laboratory must be noted.

Personal Protection Equipment (PPE) Requirements

*Please note that safety glasses also includes ANSI approved prescription glasses with side shields

General PPE – 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 (*exception: safety glasses are not required when sitting at a desk in the lab that is separated from the bench and there is minimal possibility of contamination*)	• Contamination (feet, leg, clothing, eyes, hands)	• Closed-toe, solid top shoes • Clothing that covers the legs • Safety glasses* or prescription glasses • Gloves if touching potentially contaminated equipment

Task-Specific PPE Requirements

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Directly handling hazardous materials	• Chemical, biological or radioactive material contamination (hands, eyes) • Contamination of personal clothing or skin (body)	• Safety glasses • Gloves—exam style nitrile (highly permeable and/or highly toxic materials may require different gloves—contact EHS) • Lab coat

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Working with larger volumes of flammable liquids (>4L) or heating flammable liquids	• Splashing (eyes/face) • Fire/burns (eyes, face, hands, arms, body)	• Safety glasses • Gloves – exam style nitrile • Flame resistant lab coat
	Working with larger volumes (>1L) of corrosive or toxic liquids	• Splashing (eyes, face) • Contamination/burns to unprotected skin (hands, wrists, body)	• Chemical goggles • Face shield if under pressure or outside fume hood • Gloves—utility grade nitrile or neoprene over nitrile exam style • Lab coat
	Working directly with pyrophoric and water reactive chemicals	• Burns (clothing, eyes, face, hands, body)	• Wear non-synthetic clothing • Safety glasses or chemical goggles • Face shield if splashing can occur • Nitrile gloves • Flame resistant gloves (larger volumes) • Flame resistant lab coat
	Working with cryogenic materials	• Cold burns (eyes, face, hands, body)	• Safety glasses • Face shield (larger volumes) • Thermal insulated gloves • Lab coat, apron or equivalent (larger volumes)
	Working with hot objects or equipment	• Burns (eyes, face, hands, arms, body)	• Safety glasses • Face shield as necessary • Heat resistant gloves (with arm protection if needed) • Lab coat, apron or equivalent
	Working with open flames	• Burns (eyes, face, hands, arms, body)	• Safety glasses • Gloves – exam style nitrile • Flame resistant lab coat

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Working with apparatus under high pressure	• Cuts from glass/ material fragments (face, hands, body) • Chemical contamination (eyes, face, hands, body)	• Safety glasses or goggles • Face shield • Utility gloves • Chemical resistant apron as necessary
	Working with highly reactive or explosive chemicals	• Cuts from glass/ material fragments (face, hands, body) • Chemical contamination (eyes, face, hands, body) • Fire	• 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 • Chemical resistant apron
	Minor chemical spill cleanup (if <1 liter of low hazard chemical, and respiratory protection is not required)	• Chemical contamination (shoes, eyes, hands, clothing)	• Shoe covers as necessary • Safety glasses or goggles • Double nitrile gloves or utility grade gloves over nitrile exam gloves • Lab coat
	UV light sources	• Burns (eyes, face, neck, hands, wrist)	• Full face shield (polycarbonate) over safety glasses • Nitrile gloves (wrists fully covered) • Lab coat
	Handling animals in a laboratory	• 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)	• 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

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Working with radioactive materials	• Contamination of personal clothing (body) • Radioactive material contamination (eyes, hands, wrists, skin)	• 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	• Contamination of personal clothing (shoes, body) • Radioactive material contamination (eyes, hands, wrists, skin) • Inhalation of volatile material (respiratory)	• Shoe covers • Safety glasses* • Double gloves • Sleeve covers • Lab coat • Personal radiation badge • Survey meter with scintillation probe • Benchtop radiation shielding
	Operating analytical or diagnostic x-ray generating equipment (fluoroscopy, XRD, XRF, patient procedures, etc.)	• Radiation exposure (body) • If patient or human subject, standard precautions • If laboratory animals, allergens (respiratory or transfer to mucous membranes of the eyes, nose or mouth)	• Lead apron or use of structural radiation shielding as appropriate • Personal radiation badge and ring if assigned • Survey Meter as appropriate • Gloves, as appropriate • Lab coat, gown or approved uniform, as appropriate
	Working with open table Class 3B or 4 Lasers	• Ocular and skin exposure (eyes, face, hands, body)	• Protective eyewear of proper optical density • Face shield for UV Lasers • Appropriate gloves for UV lasers • Lab coat for UV lasers • No jewelry or reflective items worn
	Working at a microscope in the laboratory	• Hazardous material contamination (hands) • Contamination of personal clothing (body)	• (If necessary, safety glasses may be temporarily removed while viewing materials via a microscope) • Gloves if touching potentially contaminated material • Lab coat or gown

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Using an autoclave	• Contamination/burns (eyes, face, hands, body)	• Lab coat • Face shield • Heat resistant apron • Heat resistant gloves
	Working when exposed to fall hazards (4 feet or greater without guardrails)	• Fall to lower level (body)	• Active fall protection (requires site specific training)
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 • For other experiments, researchers can refer to the Gradations of Risk Table referenced in this document.			
	Work with Risk Group 1 materials that do not cause disease in humans (i.e. non-pathogenic strains of E. coli, *Bacillus subtillus*, *Saccharomyces cerevisiae*, rodent cell lines)	• 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)	• Safety glasses • Gloves • Lab coat • Surgical mask or respirator, if specified
	Working with human blood, tissues, body fluids, human cell lines, or Risk Group 2 bloodborne pathogens, utilizing Universal Precautions and BSL2 containment.	• Potentially infectious materials by splash (to mucous membranes of the eyes, nose or mouth, or through non-intact skin) • Puncture by contaminated sharps (skin—percutaneous)	• Safety glasses • Mask or face shield if splashing is possible • Gloves—nitrile exam and/or cut-resistant • Lab coat or gown • Surgical mask or respirator, if specified • Additional PPE may be required based on risk to the individual

Applies	Activities/Jobs/Tasks	Potential Exposures Addressed by PPE	Personal Protective Equipment Requirements
	Experiments involving Risk Group 2 agents, that represent a moderate risk to the individual and may cause disease of varying severity. Examples of Risk Group 2 agents include *Plasmodium falciparum, Salmonella typhimurium*, Herpes Simplex Virus and *Cryptococcus neoformans*)	• Exposure to agent (eyes, hands, skin) • Puncture by contaminated sharps (skin—percutaneous) • Ingestion (eyes, nose or mouth) • Aerosol production can create potential risk of inhalation and contamination of surrounding surfaces (respiratory)	• Safety glasses • Gloves • Lab coat or gown • Respirator, if specified • Additional PPE may be required based on risk to the individual • Confine aerosols as close as possible to their point of generation • Use a biosafety cabinet or other engineering control
	Experiments with Risk Group 3 agents (i.e. West Nile Virus, *Mycobacterium tuberculosis, Histoplasma capsulatum)* in cell culture or animal laboratories	• All RG2 routes of exposure may be applicable (eyes, nose, mouth, hands, respiratory, skin) • Inhalation is of particular concern for pathogens classified at Risk Group 3 (respiratory)	• All work with RG3 agents must be conducted under primary containment using BSL3 containment practices. Specialized laboratories are required for this work. • **All procedures with RG3 agents must be approved by the Yale Biological Safety Committee** • Full face protection—face shield or safety glasses and mask • Gloves—exam, two pairs • Gown—back-fastening • Additional PPE may be required based on risk to the individual, such as respiratory protection, protective sleeve covers, booties, jump suits, etc.
	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.	• All routes of exposure (percutaneous, inhalation, ingestion, and via facial mucous membranes) may be involved with these experiments.	• **Work with Risk Group 4 Agents is not allowed at Yale University.**

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	Trinitrocresol	Trinitronaphthalene
Trinitrophenol	Trinitroresorcinol	Trinitrotoluene
Urea nitrate		

Potentially Explosive Compound Classes		
Acetylene (-C=C-)	Acyl hypohalites (RCO-OX)	Azide Organic (R-N3)
Azide Metal (M-N3)	Azo (-N=N-)	Diazo (=N=N)
Diazosulphide (-N=N-S-N=N-)	Diazonium salts (R-N2+)	Fulminate (-CNO)
Halogen Amine (=N-X)	Nitrate (-ONO2)	Nitro (-NO2)
Aromatic or Aliphatic Nitramine (=N-NO2) (-NH-NO2)	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 (BrO3-)	Chlorate salts (ClO3-)	Chlorite salts (Cl02-)
Perchlorate salts (Cl04-)	Picrate salts (2,4,6-trinitrophenoxide)	Picramate salts (2-amino-4,6-dinitrophenoxide)
Hypohalite salts (XO-)	Iodate salts (IO3-)	

Examples of strong oxidizers include:

- Ammonium perchlorate (Class 4)
- Ammonium permanganate (Class 4)
- Chromic acid (Class 2)
- Hydrogen peroxide (>27.5-52% Class 2, >52-91% Class 3)
- Mangesium peroxide (Class 1)
- Nitric Acid (≤40% Class 1, >40-86% Class 2)
- Perchloric acid (>50-60% Class 2, >60-72% Class 3, >72% Class 4)
- Potassium bromate (Class 3)
- Potassium 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 that may form explosive peroxides without concentration. ***Discard within 3 months after opening***	**Class B** Chemicals that may form peroxides upon concentration (distillation/evaporation). ***Discard within 12 months after opening***	**Class C** Chemicals that may auto-polymerize as a result of peroxide accumulation. ***Discard within 12 months after opening***
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. DOI: https://doi.org/10.17226/12654

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		Chemical	CAS
1,1-dimethylhydrazine (UDMH)	57-14-7		cobalt and cobalt compounds	various
1,2-Dibromo-3-chloropropane	96-12-8			
1,2-dichloroethane	107-06-2		Cyclophosphamide	50-18-0
1,3-butadiene	106-99-0		Diazoaminobenzene	136-35-6
1,3-Propane sultone	1120-71-4		Dibenz[a,h]anthracene	53-70-3
1,4-dioxane (p-dioxane)	123-91-1		Diepoxybutane	1464-53-5
1,4-Butanediol dimethanesulfonate (myleran, busulfan)	55-98-1		Diethylstilbestrol (DES)	56-53-1
1-Methyl-3-nitro-1-nitrosoguanidine (MNNG)	70-25-7		Diethyl sulfate	64-67-5
2-Acetylaminofluorene	53-96-3		Dimethyl sulfate	77-78-1
2-Aminofluorene	153-78-6		Ethyl methane sulfonate	62-50-0
2-Ethoxyethanol (ethyl cellosolve)	110-80-5		Ethylene dibromide	106-93-4
2-Ethoxyethylacetate (cellosolve acetate)	111-15-9		Ethyleneimine	151-56-4
2-Methoxyethanol (methyl cellosolve)	109-86-4		Ethylene oxide	75-21-8
2-Methoxyethylacetate (methyl cellosolve acetate)	110-49-6		Formaldehyde (formalin)	50-00-0
2-naphthylamine	91-59-8		Furan	110-00-9
2-nitropropane	79-46-9		hexamethylphosphoramide	680-31-9
3-Methylcholanthrene	56-49-5		Hydrazine	302-01-2
3,3'-Dichlorobenzidine (& its salts)	91-94-1		isoprene	78-79-5
3,3'-Dimethylbenzidine (o-Tolidine)	119-93-7		lead and lead compounds	various
4,4'-Methylene bis(2-chloroaniline) (MOCA)	101-14-4		Methylmercury and other organic mercury compounds	various
4,4-methylenedianiline	101-77-9		Methyl methane sulfonate	66-27-3
4-Aminodiphenyl	92-67-1		Methylene chloride (dichloromethane)	75-09-2
4-Dimethylaminoazobenzene (p-dimethylaminoazobenzene)	60-11-7		Methyl chloromethyl ether	107-30-2
4-Nitrobiphenyl	92-93-3		Nickel and nickel compounds	various
7,12-Dimethylbenz[a]anthracene	57-97-6		Nitrobenzene	98-95-3

Acetaldehyde	75-070-0		Nitromethane	75-52-5
Acrylamide (solid form)	79-06-1		N, N-bis(2-chloroethyl)-2-naphthylamine (chlornaphazine)	494-03-1
Acrylonitrile	107-13-1		N-Nitrosodiethylamine	55-18-5
alpha-Naphthylamine (1-Naphthylamine)	134-32-7		N-Nitrosodimethylamine	62-75-9
Arsenic and arsenic compounds	various		N-Nitrosodi-n-butylamine	924-16-3
			N-Nitrosodi-n-propylamine	86-30-6
			N-Nitroso-N-ethylurea	759-73-9
Benz[a]anthracene	56-55-3		N-Nitroso-N-methylurea	684-93-5
Benzene	71-43-2		N-Nitroso-N-methylurethane	615-53-2
Benzidine	92-87-5		N-Nitrosopiperidine	100-75-4
Benzo[a]pyrene	50-32-8		o-Aminoazotoluene	97-56-3
beryllium	7440-41-7		Perchloroethylene	127-18-4
Beryllium compounds	various		Polyclorinated biphenyls (PCBs)	various
beta-Naphthylamine (2-Naphthylamine)	91-59-8			
beta-Propiolactone	57-57-8		propylene oxide (epoxypropane)	75-56-9
bis-chloromethyl ether	542-88-1		Propylenimine (2-methylaziridine)	75-55-8
bromodichloromethane	75-27-4		Styrene	100-42-5
Cadmium and cadmium compounds	various			
			Thioacetamide	62-55-5
Carbon tetrachloride	56-23-5		Toluene diisocyanates (TDI)	26471-62-5
Chemotherapy agents	various		trichloroethylene (TCE)	79-1-6
Chlornaphazine	494-03-1		Uracil mustard	66-75-1
Chloroethylene (vinyl chloride)	75-01-4		Urethane (ethyl carbamate)	51-79-6
Chloroform	67-66-3		vinyl magnesium bromide	1826-67-1
chromium compounds (VI)	various			