



MASSACHUSETTS INSTITUTE OF TECHNOLOGY

# Chemical Hygiene Plan

Revision 24: August 4, 2022

## Materials Research Laboratory

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## PART I. Getting Started

### 1. INTRODUCTION

#### 1.1. Purpose, Policy, and Scope

##### Purpose

This document constitutes the Chemical Hygiene Plan (CHP) required by the U.S. Occupational Safety and Health Act (OSHA) of 1970 and regulations of the U.S. Department of Labor including 29 CFR 1910.1450 "Occupational Exposure to Hazardous Chemicals in Laboratories" (the "Laboratory Standard"). The purpose of the Plan is to describe the proper use and handling practices and procedures to be followed by employees, students, visitors, and other personnel working in each laboratory of the **Materials Research Laboratory (MRL)** to protect them from potential health and physical hazards presented by chemicals used in the workplace, and to keep chemical exposures below specified limits. While the Plan establishes work practices to promote safety in the laboratory, each individual has the first responsibility for ensuring that good health and safety practices are implemented in the laboratory. Not only does this individual responsibility promote personal well-being and the well-being of others, it also advances MIT's commitment to excellence in research.

##### Policy and Scope

It is the policy of the Massachusetts Institute of Technology (as represented by the MIT Corporation and the Office of the President) to provide a safe and healthy workplace in compliance with OSHA regulations including the "Laboratory Standard" referenced above. A link to the full OSHA Laboratory Standard is included in Part I. Section 4.1. of this Chemical Hygiene Plan. This Plan which is located in the MRL EHS Coordinator's office 13-2014 applies to all laboratories in MRL and all personnel who supervise or work in these labs. This Plan also applies to non-laboratory areas, and the additional special provisions to ensure these non-laboratory areas are in compliance with OSHA regulations pertaining to the Hazard Communication Standard are included in Part IV, Section 7 of this Plan.

#### 1.2. Plan Organization

**Part I. Getting Started** contains the basic, minimal information laboratory personnel need to know before using hazardous chemicals. It is designed to get laboratory personnel directly to the relevant information they need before beginning their laboratory work. This Part contains the purpose, policy, and scope of the Plan, and defines the roles and responsibilities for developing and implementing the Plan. Requirements for training and chemical information available to personnel are also detailed here.

**Part II. General Chemical Hygiene Practices** contains the minimum required precautions and standard operating procedures for working with laboratory chemicals in MIT laboratories. These precautions address broad classes of chemicals. This Part contains chemical hazard and risk assessment information, and general procedures for safe chemical management addressing the purchase, use, labeling, storage, disposal and shipping of chemicals. This Part also discusses common controls for safe use of chemicals including administrative and engineering controls.

**Part III. Department, Lab, or Center-Specific Chemical Hygiene Practices or Lab Specific Standard Operating Procedures** contains standard operating procedures generated by the Department, Laboratory, or Center or by a specific laboratory for specialized materials, procedures, or practices related to chemical use that are not adequately addressed in Part II. of this Plan. This Part is provided to enable individual Department, Laboratories, or Centers or individual laboratories to customize this Chemical Hygiene Plan for their specific operations and hazards. A Lab Specific SOP Template is contained in this Part to provide assistance to laboratory personnel generating specific safety procedures.

**Part IV. Additional Administrative Provisions** contains information and procedures essential to a successful chemical hygiene program that address activities other than the direct handling and use of hazardous chemicals. These additional administrative provisions include information on MIT's Environment, Health and Safety Management System; prior approval and procurement requirements; medical evaluations and assessments; record keeping; laboratory inspections and audits; compliance and enforcement; and other related federal regulations that impact chemical use at MIT.

#### **Part V. Personnel Covered by this Plan**

This Chemical Hygiene and Safety Plan applies to all work involving hazardous substances or activities conducted in space assigned to MRL as defined in the MIT In-site Report Room List. Visitors and individuals holding appointments in other MIT departments who plan to conduct research in MRL laboratories must read and understand the MRL Chemical Hygiene and Safety Plan and must pass the Institute developed web-based training courses and related exams. MRL requires that the individual's laboratory supervisor certify that he or she has read and understood the plan and has been given safety training relevant to their work.

## **2. ROLES AND RESPONSIBILITIES**

An essential component of any chemical hygiene program is to clearly articulate and clarify the different roles and responsibilities of all the stakeholders who work or visit in areas where chemicals are present. Clarifying roles and responsibilities for implementing the Chemical Hygiene Plan (CHP) will establish accountability, streamline processes, enhance safety, and avoid confusion and questions in meeting the Plan's objectives.

### **2.1. Materials Research Laboratory Director: Prof. Carl V. Thompson**

The DEPARTMENT, LAB, or CENTER CHAIR shall:

- A. Ensure the Chemical Hygiene Plan is written and updated.
- B. Appoint the Chemical Hygiene Officer (CHO). The individual selected must be qualified by training or experience to provide technical guidance in the development and implementation of this written Chemical Hygiene Plan. This individual must have appropriate authority to assist with implementation and administration of the Chemical Hygiene Plan.
- C. Provide or obtain administrative and financial support, as needed, for implementing and maintaining the Chemical Hygiene Plan and the requirements of the Plan.

## **2.2. The CHEMICAL HYGIENE OFFICER: Prof. Carl V. Thompson**

The Chemical Hygiene Officer shall:

- A. Know and understand the requirements of the OSHA Laboratory Standard regulation (29CFR 1910.1450) and the DLC Chemical Hygiene Plan.
- B. Oversee the implementation of the CHP in the Department, Lab, or Center and assist Principal Investigators or Supervisors (PI/Supervisors) with implementing the Chemical Hygiene Plan within their laboratory.
- C. Ensure the Plan is distributed or made available to all in the DLC who are impacted by the Plan.
- D. Submit one copy of the CHP electronically to the MIT Environment, Health and Safety (EHS) Office for reference use and to facilitate the annual update process.
- E. Advise Principal Investigators or Supervisors concerning adequate facilities, controls, and procedures for work with unusually hazardous chemicals.
- F. Seek ways to improve the Chemical Hygiene Plan.
- G. Review and update the Chemical Hygiene Plan annually, when directed by the EHS Office.
- H. Support the EHS Coordinator, as needed, with inspection and audit activities and other requirements of the EHS Management System, such as the Space Registration Database.
- I. Participate in investigation of serious accidents involving hazardous chemicals, acting as a liaison to the EHS Office.
- I. Assist PI/Supervisors, as needed, with obtaining services or supplies and equipment for correcting chemical hygiene problems or addressing chemical hygiene needs.
- J. Ensure periodic exposure monitoring requirements are met and maintain monitoring records.
- K. If requested, review proposed experiments or Lab Specific SOPs for significant environment, health, and safety issues, and/or contact the EHS Office to address concerns.
- L. Co-Chair the DLC-EHS Committee with the EHS Coordinator.
- M. Attend annual CHO meeting conducted by the EHS Office.

## **2.3. The EHS COORDINATOR: Lars Llorente**

The ENVIRONMENT, HEALTH AND SAFETY (EHS) COORDINATOR shall:

- A. Provide assistance to the CHO, if appropriate and as requested, with developing and implementing the DLC Chemical Hygiene Plan.
- B. Be familiar with the DLC Chemical Hygiene Plan.
- C. Compile information from the laboratory for the EHS Space Registration Database.
- D. Ensure routine inspections are conducted in the laboratory areas.
- E. Participate in biannual inspections of laboratory operations.
- F. Ensure DLC staff receives training required by regulation for safe handling and proper disposal of chemicals and that the training is documented.
- G. Serve as contact point for arranging special studies or support from the EHS Office.
- H. Act as a contact for Building Services and Repair and Maintenance staff to address concerns regarding safety for work in the laboratory area.
- I. Ensure appropriate local records are collected and maintained for inspections, inspection follow-up, and lab-specific training for three years.
- J. Arrange for decommissioning of laboratory space.

## **2.4. The PRINCIPAL INVESTIGATOR or LABORATORY SUPERVISOR**

The PRINCIPAL INVESTIGATOR or LABORATORY SUPERVISOR (PI/Supervisor) shall:

- A. Be familiar with this Chemical Hygiene Plan and ensure that all work is conducted in accordance with requirements of this Plan. They should contact the CHO for advice and assistance regarding this Plan and implementing the provisions of this Plan when needed.

- B. The PI has the authority to take whatever actions necessary to assure the laboratory operates in a safe manner. This can include temporarily restricting access to the lab until any issues are resolved.
- C. Assess all chemicals in the research laboratories under their purview, and ensure measures are established for safe use, storage, and disposal of the hazardous chemicals within the laboratory. Such measures include:
  - 1. Preparing additional, Lab Specific SOPs for work with potentially hazardous chemicals, equipment or processes when needed. See Part II. Section 3 for more information on when additional Lab Specific SOPs are required.
  - 2. Providing personal protective equipment needed for safe handling of the chemicals.
  - 3. Providing proper containers, containment, and cabinetry for safe storage of materials.
  - 4. Defining the location and processes where particularly hazardous substances will be used, ensuring these areas are labeled, and ensuring that an inventory of these substances is maintained.
  - 5. Pay particular attention and conduct a risk assessment for all work that researchers are conducting alone and in the case of undergraduates, you must provide written prior approval for working alone with hazardous substances, equipment, or operations
- D. Ensure new processes or experiments involving hazardous materials are planned carefully and appropriate hazard information, safety equipment, and general or Lab Specific SOPs are available prior to commencing work. Always seek to minimize the amount of hazardous chemicals purchased and used for experiments or processes.
- E. Ensure the information regarding the laboratory activities recorded in the Space Registration Database is accurate. This should include emergency contact information to be used in the generation of emergency "green card" laboratory door signs.
- F. Plan for accidents and ensure that appropriate supplies are in place and procedures are established for responding to an accident, including cleaning up chemical spills.
- G. Ensure all employees working in the laboratory receive required training for work with potentially hazardous chemical, including lab-specific training on the hazardous materials that they use. See Part I. Section 3. Follow procedures for documenting the lab-specific training.
- H. Ensure that all personnel obtain medical examinations and participate in the MIT medical surveillance program when required due to the materials they are working with.
- I. Monitor the safety performance of the staff to ensure that the required safety equipment, practices and techniques are understood and are being employed and ensure that action is taken to correct work practices that may lead to chemical exposures or releases.
- J. When needed, contact the Environment, Health and Safety (EHS) Office to arrange for workplace air samples, swipes or other tests to determine the amount and nature of airborne and/or surface contamination, inform employees and students of the results, and use data to aid in the evaluation and maintenance of appropriate laboratory conditions.
- K. Ensure laboratory inspections are conducted routinely, and address all areas prescribed in the Level I. and II. Inspections as outlined in Part IV. Section 6. Take action to correct conditions that may lead to accidents or exposure to hazardous chemicals, and to correct problems identified during inspections. See Part IV. Section 6. for more information.
- L. Ensure employees who suspect they may have received an excessive exposure to a hazardous chemical report to the MIT Medical Department for assessment. Such exposures may occur through accidental inoculation, ingestion, or inhalation of the chemical.
- M. Report all accidents involving an employee's chemical exposure or involving a chemical spill that may constitute a danger of environmental contamination to the EHS Office, the CHO or EHS Coordinator.
- N. Investigate all chemical accidents and near misses to determine the cause and take appropriate corrective action to prevent similar accidents. Contact the CHO or the EHS Office, when needed, for assistance with investigations, assessment, and recommendations for corrective action.

- O. Ensure unwanted or excess hazardous chemicals and materials are properly disposed according to all MIT, state, and federal procedures.
- P. Assist the EHS Office, EHS Coordinator, and CHO as requested.
- Q. Ensure shipping of all hazardous material is done following all state and federal regulations refer to Part II Section 9 Shipping Dangerous and Hazardous Materials on page 37 of this plan. Following the prudent laboratory practices and risk communication methods outlined in this Chemical Hygiene Plan are key elements in ensuring the Institute's compliance with TSCA requirements. Refer to Part 1, Section 2 of the Plan for these general responsibilities. With respect to materials regulated under TSCA, PIs shall ensure that any research agreements, experimental efforts and transfer of materials from the lab are consistent with the definition of "research and development activity" outlined in the EHS SOP "Toxic Substances Control Act (TSCA): Procedures for Core Program Compliance". The EHS Office shall work with Departments to ensure that any required TSCA forms (Import/Export, Allegations of Adverse Reactions, Notification of Substantial Risk and the TSCA New Chemical Transfer Form) are completed; maintain TSCA records; ensure that TSCA compliance updates are communicated; and, support Chemical Hygiene Officers/EHS Coordinators in conducting incident/illness/injury investigations involving new chemicals for which little environmental and health effects information is available (or for existing chemicals, when new symptoms are exhibited). Laboratory personnel shall contact the EHS Office when a chemical sample will be shipped; when a chemical will be imported into or exported from the U.S.; and, when adverse environmental or human health effects for a new or existing chemical are observed.
- R. Undergraduates shall not work alone with hazardous materials, equipment or operations that can result in immediate injury or death without prior written approval from the immediate PI or supervisor. Written approval should only be granted after the risk assessment is performed and reviewed by the PI or supervisor with the individual

**Laboratory, SEF and Teaching Lab Supervisors and PIs**

The following is a list of our Teaching Lab and SEF supervisors:

MRL Electron Microscopy Facility	Dr. Yong Zhang
MRL Electron Microscopy Facility	Patrick Boisvert
MRL Analytical Facility	Elisabeth Shaw
MRL Analytical Facility	Timothy McClure
MRL X-ray Diffraction Facility	Dr. Charlie Settens
MRL Physics Teaching Lab	Prof. Riccardo Comin
DMSE Teaching Lab	Dr. Shaymus Hudson

**2.5 The EHS REPRESENTATIVE**

The ENVIRONMENT, HEALTH AND SAFETY (EHS) REPRESENTATIVE shall:

- A. Be familiar with the content and requirements of this Chemical Hygiene Plan and assist the Principal Investigator or Supervisor, as directed, with implementing and complying with requirements of this Plan.
- B. Assist with contacting the DLC EHS Coordinator or the CHO, when needed, for assistance with addressing requirements for safe handling of chemicals.
- C. Assist with or provide lab-specific chemical hygiene training for laboratory personnel, as directed by the PI/Supervisor.
- D. Assist with dissemination of EHS information to laboratory personnel.
- E. Assist with required routine inspections of the laboratory, correcting problems that can be readily corrected.
- F. Assist with ensuring essential supplies and equipment are in place for safe work in the laboratory.
- G. Assist with monitoring staff work practices for safety.
- H. Report safety problems or concerns to the PI/Supervisor and/or the EHS Coordinator.



- I. Address, as directed, safety problems or concerns in the laboratory.
- J. Review and be familiar with DLC Emergency Preparedness Plan.

## 2.6 The ENVIRONMENT, HEALTH and SAFETY (EHS) OFFICE

N52-496, tel. 617-452-3477 <http://ehs.mit.edu/site/> off hours: 617-253-4948

The ENVIRONMENT, HEALTH, and SAFETY (EHS) OFFICE shall:

- A. Oversee process for annual update of the CHP, reminding CHOs and EHS Coordinators when annual CHP updates are due and reviewing updated plans. See the *CHP Preparer's Guide* on the CHP website <https://ehs.mit.edu/chemical-safety-program/chemical-hygiene> for more information on the annual update process.
- B. Provide a standard CHP template for use in developing and updating Chemical Hygiene Plans.
- C. Provide "General Chemical Hygiene" training by classroom, web, or when requested by a DLC.
- D. Provide "Managing Hazardous Waste" training by classroom, web, or when requested by a DLC.
- E. Provide materials and guidance to assist with Lab-Specific Chemical Hygiene Training.
- F. Establish and maintain a system for maintaining training records.
- G. Conduct an annual meeting for CHOs and EHS Coordinators to update them regarding changes in the Template, the EHS Management System, and to review significant chemical safety concerns from the year.
- H. Conduct special investigations and exposure monitoring, as requested or as required by regulations, making recommendations for control when needed.
- I. Participate in inspections of laboratory operations at least once a year.
- J. Oversee the fume hood survey program.
- K. Provide guidance regarding selection and use of personal protective equipment. When respirators are required, provide services to ensure personnel are provided the proper equipment, to ensure the equipment fits properly, and to ensure users receive the required training.
- L. Provide guidance and review Lab Specific SOPs for new experiments or operations, as requested.
- M. Provide, as requested, chemical safety information and guidance for appropriate controls of hazards such as proper personal protective equipment and local exhaust ventilation.
- N. Assist with investigations of serious accidents or chemical exposure incidents.
- O. Report all DLC-specific accidents and incidents, as appropriate, to the DLC EHS Coordinator.
- P. Available both in emergency situations and in an advisory capacity to answer questions from anyone at the Institute. These services provide 24-hour on-call personnel to respond to off-hours needs

## 2.7. EMPLOYEES, STAFF, STUDENTS

It is the responsibility of employees, staff and students to follow the procedures outlined in this Chemical Hygiene Plan and all standard operating procedures developed under the plan. Failure to comply with safety procedures could result in researchers being denied access to the department laboratories where hazardous chemicals are in use. The responsibilities of employees, staff and students working with or around chemicals in the laboratory include:

- A. Read and understand the OSHA Chemical *Laboratory Standard* and this Chemical Hygiene Plan.
- B. Understand the hazards of chemicals they handle and the signs and symptoms of excessive exposure.
- C. Understand and follow all standard operating procedures.
- D. Understand and apply all training received.
- E. Understand the function and proper use of all personal protective equipment and wear personal protective equipment when mandated or necessary.

- F. Report to the Principal Investigator or Laboratory Supervisor any significant problems arising from the implementation of the standard operating procedures.
- G. Report to the PI/Supervisor all facts pertaining to every accident that results in exposure to toxic chemicals.
- H. Report to the PI/Supervisor or EHS Representative actions or conditions that may exist that could result in an accident.
- I. Contact the PI/Supervisor, the Chemical Hygiene Officer, the EHS Coordinator, or the EHS Office if any of the above procedures are not clearly understood.
- J. If an emergency occurs related to an experiment, provide emergency response personnel with information about the conditions that caused the emergency and the existing situation in the laboratory.

## 2.8. VISITORS, TOURS and PETS

To ensure the health and safety of visitors and tours to laboratories where potential hazards may exist, guidelines should be followed, which can be found in an EHS SOPs entitled "[Visitors and Tours Guideline](#)," # EHS-0036, located at <https://ehs.mit.edu/sops> (certificate login is required).

The Institute promotes a healthy learning and research environment by controlling potential health hazards and nuisances including **prohibiting pets** from laboratories and other registered spaces with hazards. **This is for the safety and protection of the researchers, their work and the pet itself.** The definition of a pet is a domestic animal kept for personal enjoyment or companionship and is not trained to perform any disability-related tasks or work. The exception is for police dogs and animals used in research and teaching. For questions or further guidance related to pets, contact the EHS Office at [environment@mit.edu](mailto:environment@mit.edu).

## 2.9. MATERIALS RESEARCH LABORATORY EHS COMMITTEE

With respect to the Chemical Hygiene Plan, the MRL EHS Committee shall:

- A. Participate in periodic inspections and/or review inspection reports of DLC's laboratories and facilities, providing guidance or directives, as needed, for correcting problems found.
- B. Review chemical handling incidents or exposure issues that occur in the DLC and recommend appropriate corrective action.

## 3. TRAINING

MIT has established systems to ensure you are provided with OSHA-required training to inform you of the hazards and precautions for work with chemicals, including chemicals present in your work area. The process begins when you complete a web-based *Training Needs Assessment*. You answer questions specific to your research situation and job duties, and the system will provide you information on your training needs and requirements. You should then proceed to take the required web courses or sign up for classroom training. As a researcher or employee working in a laboratory at MIT, you must complete the *Training Needs Assessment*, and can do so by going to <https://ehs.mit.edu/training/>.

This will take you to a page that will direct you further. If you have problems or questions regarding completing the *Training Needs Assessment*, you should contact your EHS Coordinator or your EHS Representative.

### 3.1. Training Requirements

Chemical hygiene training requirements are detailed in the EHS-MS training system, which can be accessed at <https://ehs.mit.edu/training/>. The following four components are required if you indicate in the *Training Needs Assessment* within the training system that you use potentially hazardous chemicals in a laboratory,

or you are a Principal Investigator or Supervisor for those who use potentially hazardous chemicals in a laboratory.

- A. General Chemical Hygiene Training** – can be taken as a web-based course or taken by attending a class offered by the Environment, Health and Safety (EHS) Office. This course is required only once before beginning work with potentially hazardous chemicals in a laboratory.
- B. Read the Chemical Hygiene Plan** – Signing a confirmation of having read and understood the Plan is required one time before beginning work with potentially hazardous chemicals in a laboratory.
- C. Lab-Specific Chemical Hygiene Training** – provided by the Principal Investigator or his or her designee on lab-specific chemical hazards. This training is required before beginning work with potentially hazardous chemicals in a laboratory including chemicals developed in the lab for use exclusively in the lab. These chemicals require a hazard determination and training if the chemical is considered hazardous. Training is also done annually thereafter (usually within a lab group meeting) or whenever a new hazard is introduced. The topics covered will depend, in part, on the nature of the lab and research being done. Discuss Lab-Specific Chemical Hygiene Training questions and requirements with your PI/Supervisor, EHS Representative, Chemical Hygiene Officer or your EHS Coordinator.
- D. Managing Hazardous Waste** – can be taken as a web-based course or taken by attending a class offered by the EHS Office. Required before beginning work with potentially hazardous chemicals and annually thereafter.

### 3.2. Training Records

The PI/Supervisor or designee will keep a copy of the outline of the topics covered in Lab-Specific Chemical Hygiene Training. The roster or lists of researchers, who have completed the lab-specific training and read the Chemical Hygiene Plan, will be submitted to the EHS Coordinator. These training records are then entered into the EHS-MS Central Training Records Database. Training records are kept for at least 3 years after an employee or student leaves the Institute.

## 4. INFORMATION REQUIREMENTS

### 4.1. Basic Requirements

**Information** that must be available to laboratory personnel includes:

- A.** A copy of the OSHA *Laboratory Standard* and its Appendices. The *Laboratory Standard* can be accessed on the OSHA website via <http://www.osha.gov> and searching under the regulation number “1910.1450”.
- B.** The Permissible Exposure Limits (PELs) for OSHA-regulated substances and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) for hazardous substances not given OSHA PELs. These lists are provided via a web link in Appendix II-A and II-B of this document.
- C.** Signs and symptoms associated with exposure to hazardous substances used in the laboratory. General information is integrated into Part II, Sections 2. and 3. of this document.
- D.** The location and availability of known reference materials on hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory. This information is provided in the next section of this document.
- E.** In addition, your supervisor, Chemical Hygiene Officer, EHS Coordinator and EHS Office staff are available to provide safety information. Core safety information sources are discussed below.

### 4.2. Chemical Safety Information Sources

#### **Safety Data Sheets (SDSs)**

Safety Data Sheets (SDSs) are documents, prepared by chemical manufacturers, that provide information about the chemical’s physical and chemical hazards and recommended exposure limits, and list the means for controlling those hazards. SDSs also provide information about first aid, emergency procedures, and waste disposal.

An SDS should be reviewed before beginning work with a chemical to determine proper use and safety precautions. Once a chemical is present in the lab, the SDS should be either book marked electronically or a hard copy kept on hand for reference, or in case of emergencies. Specific information required by OSHA to be on an SDS includes:

Product Identity	Reactivity Hazards
Hazardous Ingredients	Spill Clean-Up
Physical/Chemical Properties	Protective Equipment
Fire and Explosion Hazards	Special Precautions
Health Hazards and Exposure Limits	

SDSs and additional chemical hazard information can be obtained from a variety of sources as outlined below:

- A. **The Internet.** The EHS Office has compiled a list of links to sites that contain SDSs. This list can be accessed at <https://ehs.mit.edu/workplace-safety-program/hazard-communication/>
- B. **Chemical Manufacturer.** A request may be made directly to the chemical manufacturer or supplier. This is often the best source for “products” or “mixtures” to determine what hazardous ingredients are contained in the formulation.
- C. **EHS Office.** A file of SDSs for common chemicals that are in use at MIT or have been used at MIT is available through the EHS Office on the fourth floor of Building N52. They can be reached at 617-452-3477 (2-EHSS or 2-3477 from an MIT telephone).
- D. **MRL Library.** Located in 13-2014 for *Prudent Practices in the Laboratory, Prudent Practices for Disposal of Chemicals from Laboratories and Handbook of Reactive Chemical Hazards*

Please contact the EHS Office if you need assistance in interpreting SDS information.

### Safety Data Sheets

In spring of 2012, the Occupational Safety and Health Administration finalized an update of the OSHA Hazard Communication Standard to adopt international Global Harmonization System criteria for:

- Classifying the hazards of chemicals and chemical products and mixtures.
- Labeling of hazardous materials with standardized pictograms and standardized language to indicate hazards and precautions
- Conveying the hazard information on a standardized 16 section Safety Data Sheet.

By June 1, 2015, manufacturers will be required to generate Safety Data Sheets in place of Material Safety Data Sheets. Safety Data Sheets will have a standardized 16 section format with standardized information in each section. **Appendix 10.2** contains a summary of information about the new “Safety Data Sheet” sections and section content. More details can be found on the EHS Office web page: <https://ehs.mit.edu/workplace-safety-program/hazard-communication/>.

Some of the suppliers of laboratory chemicals are already generating data sheets in this new format. Until June 1, 2016, you can have either an MSDS or an SDS available for the chemicals you work with. After June 1, 2016, you will need to have replaced all MSDSs with paper copies or links to SDSs for the chemicals you work with in the laboratory.

### Newly Synthesized Chemicals and SDS Requirements

New chemical substances synthesized or produced in your laboratory and used or shared *outside* of your laboratory suite are subject to OSHA Hazard Communication Standard (29 CFR 1910.1200) requirements. These rules mandate the preparation of a Safety Data Sheet for each synthesized substance and labeling of containers containing the chemical substance.

### Laboratory Chemical Safety Summaries (LCSS)

The LCSSs provide concise, critical discussions of the toxicity, flammability, reactivity, and explosiveness of 88 chemicals commonly used in scientific research laboratories. These are particularly useful as they address laboratory use of chemicals. <https://pubchem.ncbi.nlm.nih.gov/lcss/>

### **Chemical Container Labels**

Chemical container labels are a good resource for information on chemical hazards. All containers of hazardous chemicals must have labels attached. Labels on purchased chemicals must include:

- ❑ The common name of the chemical;
- ❑ The name, address and telephone number of the company responsible for the product; and
- ❑ Appropriate hazard warning(s). The warning may be a single word (e.g. Danger, Caution, Warning) or may identify the primary hazard both physical (e.g. water reactive, flammable, or explosive) and health (e.g. carcinogen, corrosive or irritant).

Most labels provide additional safety information to help workers protect themselves from the substance. This information may include protective measures and/or protective clothing to be used, first aid instructions, storage information and emergency procedures.

Laboratory personnel are responsible for:

- ❑ Inspecting incoming containers to be sure that labels are attached and are in good condition and contain the information outlined above.
- ❑ Reading the container label each time a newly purchased chemical is used. It is possible that the manufacturer may have added new hazard information or reformulated the product since the last purchase.
- ❑ Ensuring that chemical container labels are not removed or defaced, except when containers are empty.
- ❑ Labeling any secondary containers used in the laboratory, to prevent unknown chemicals or inadvertent reaction.
- ❑ Verifying that chemical waste containers have completed and accurate chemical waste labels.

Additional guidance on labeling chemical containers can be found in Part II. Section 6.

**Global Harmonization Pictograms and Labels.** Under the 2012 changes to the OSHA Hazard Communication Standard, requirements for language on chemical labels is standardized using the Global Harmonization System criteria, and standardized pictograms are to be used to convey the hazards. Some suppliers of laboratory chemicals have already begun to implement changes on their labels, making use of the new pictograms and language. **Appendix 10.3** contains information about the new pictograms and their meaning. It is recommended the lab post the chart of pictograms so personnel can become familiar with them and their meaning. Additional information can be found at: <https://ehs.mit.edu/workplace-safety-program/hazard-communication/>, along with a link to pictogram information for printing and posting. A color printer should be used because the red borders on the pictograms are a key component.

By June 1, 2015, all suppliers will need to label their containers using the standard labeling criteria but until then you may see different types of labels.

### **Environment, Health and Safety Reference Literature**

The EHS Office maintains a library of reference materials addressing environment, health and safety issues. These references include applicable exposure standards and recommended exposure levels, as well as copies of the OSHA Lab Standard and its Appendices. These materials, as well as additional health and safety references, may be reviewed by visiting the EHS Office located on the fourth floor of Building N52.

### **4.3. Guidance and resources for COVID-19 response**

The Institute is actively monitoring the COVID-19 situation and working with MIT researchers to ensure the safety of the MIT community while minimizing the impact on MIT's vibrant research enterprise. In response to COVID-19, the Institute has developed policies, guidance and resources, with the safety and security of our personnel being the most important guiding principle. The policies, guidance and resources may be developed, updated, or revoked as COVID-19 situation evolves.

Find the latest Institute information can be found at: <https://now.mit.edu>

## PART II. General Chemical Hygiene Practices

### 1. INTRODUCTION

Part II of this Chemical Hygiene Plan contains the minimum required precautions and standard operating procedures for working with laboratory chemicals in MIT laboratories. These precautions address broad classes of chemicals. This Part contains chemical hazard and risk assessment information, and general procedures for safe chemical management addressing the purchase, use, labeling, storage, disposal and shipping of chemicals. This Part also discusses common controls for safe use of chemicals including administrative and engineering controls, such as fume hoods, personal protective equipment, and designated areas.

Hazardous chemicals can cause harm when they enter the body in sufficient amounts via inhalation, ingestion, injection or skin absorption. Harmful effects can also occur by eye or skin contact alone. The nature of the hazardous chemical and the routes by which it enters or contacts the body determine the type of controls that are needed. The Occupational Safety and Health Administration (OSHA) and other organizations have set occupational exposure limits on airborne chemical exposure. Keeping exposures below these limits is generally believed to protect employees and students. Permissible Exposure Limits (PELs) set by OSHA are contained in Appendix II-A. Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH) are contained in Appendix II-B. For many laboratory chemicals, exposure limits have not been established. In addition, little is known about the effects of combined exposures. Therefore, all laboratory workers should take steps to minimize chemical exposure via all routes of entry.

OSHA recognizes that some classes of chemical substances pose a greater health and safety risk than others. To differentiate this different risk characteristic, OSHA identifies two categories of hazardous chemicals: **hazardous chemicals** and **particularly hazardous substances**. *Particularly hazardous substances* (PHSs) are a subset of hazardous chemicals that is regulated more stringently because they have been deemed to pose a substantially greater risk. Because of this, OSHA requires additional precautions and procedures be undertaken when *particularly hazardous substances* are used in the laboratory.

#### Introduction to Standard Operating Procedures

A standard operating procedure (SOP) is a written set of instructions or guidelines that detail the uniform procedures to be followed routinely, and safety precautions to take when carrying out a particular experiment or procedure. The development and implementation of SOPs for critical activities is a core component of promoting excellence in a laboratory and for ensuring a safe, healthy, and environmentally sound workplace. For these reasons, the use of general SOPs and the development and use of Lab Specific SOPs is an essential administrative tool to be used in the laboratory and is a tool that is required by the OSHA Laboratory Standard. The equivalent of Lab Specific SOPs should also be developed for research conducted in the field where hazardous materials or processes are used ensuring proper safety, storage and controls in the field. For more information on Field Safety visit <https://ehs.mit.edu/lab-research-program/field-research-safety/>.

Literally thousands of different compounds are involved in the research being conducted in campus laboratories. The specific health hazards associated with many of these compounds are unknown, and many substances are new compounds which have not been reported previously in the chemical literature. Consequently, it is impossible in this Chemical Hygiene Plan to provide standard operating procedures for each specific hazardous substance. Instead, this Part outlines general procedures that should be employed in the use of all hazardous substances. Individual research groups may be required to supplement these general procedures with additional Lab Specific SOPs for handling specific hazardous substances that are used in their laboratories.

This Chemical Hygiene Plan contains core standard operating procedures for the safe use of two categories of chemicals: *hazardous chemicals*, and *particularly hazardous substances* (PHS). These standard operating

procedures are contained in Part II. Section 3. These general safety procedures are designed to ensure basic levels of staff health and safety in the laboratory, for routine and common practices, uses, and chemicals.

You are required to develop additional Lab Specific SOPs if the general SOPs provided in Part II of this Plan DO NOT adequately ensure the protection of personal health and safety, and the environment for a particular activity, operation, or experiment conducted in your laboratory. This requirement is particularly applicable if a procedure requires detailed and specific guidance to avoid dangerous exposures or consequences such as an explosion. Lab Specific SOPs must be developed prior to initiating any significantly hazardous procedures.

Guidelines and a template for preparing Lab Specific SOPs when required as noted above, are contained in Part III. of this Plan. A copy of all Lab Specific SOPs developed must be located in the laboratory spaces and be available to all people in the laboratory. It is recommended, but not required, that all additional Lab Specific SOPs be included in Part III. of this Chemical Hygiene Plan.

Prior to working with chemicals following the SOPs in Part II. Section 3, there are certain steps you must take to understand the hazards of the work you are doing with chemicals. A process for assessing the hazards of chemical use is outlined below.

## 2. IDENTIFICATION AND CLASSIFICATION OF HAZARDOUS CHEMICALS

Determine the specific chemicals you are working with and the type of hazard they present. Many of the substances encountered in the laboratory are known to be toxic or corrosive, or both. Compounds that are explosive and/or are highly flammable pose another significant type of hazard. New and untested substances that may be hazardous are also frequently encountered. Thus, it is essential that all laboratory workers understand the types of toxicity, recognize the routes of exposure, and are familiar with the major hazard classes of chemicals. The most important single generalization regarding toxicity in chemical research is to treat all compounds as potentially harmful, especially new and unfamiliar materials, and work with them under conditions to minimize exposure by skin contact and inhalation.

When considering possible toxicity hazards while planning an experiment, it is important to recognize that the combination of the toxic effects of two substances may be significantly greater than the toxic effect of either substance alone. Because most chemical reactions are likely to contain mixtures of substances whose combined toxicities have never been evaluated, it is prudent to assume that mixtures of different substances (e.g., chemical reaction mixtures) will be more toxic than the most toxic ingredient contained in the mixture. Furthermore, chemical reactions involving two or more substances may form reaction products that are significantly more toxic than the starting reactants.

The OSHA Laboratory Standard defines a hazardous chemical as *"a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term 'health hazard' includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes"*. Highly flammable and explosive substances comprise a category of hazardous chemicals.

The major classes of *hazardous* and *particularly hazardous chemicals* and their related health and safety risks are discussed in further detail below.

### 2.1. Possible Animal Carcinogens

Carcinogens are chemical or physical agents that cause cancer. Generally, they are chronically toxic substances; they cause damage after repeated or long-duration exposure, and their effects may only become evident after a long latency period. Chronic toxins are particularly insidious because they may have no immediate apparent harmful effects. For a large number of compounds there is limited evidence of carcinogenicity to animals from studies involving experimental animals. These compounds should be handled using the general procedures for work with hazardous substances outlined in Part II. Section 3.1 and 3.2 below.



Certain *select carcinogens* are classified as "particularly hazardous substances" and must be handled using the additional special precautions described in Part II. Section 3.3. Select carcinogens (defined in detail below) consist of compounds for which there is evidence from human studies that exposure can cause cancer. It is important to recognize that some substances involved in research laboratories are new compounds and have not been subjected to testing for carcinogenicity.

## **2.2. Corrosive Substances**

As a health hazard, corrosive substances cause destruction of, or alterations in, living tissue by chemical action at the site of contact. Major classes of corrosive substances include strong acids (e.g., sulfuric, nitric, hydrochloric, and hydrofluoric acids), strong bases (sodium hydroxide, potassium hydroxide, and ammonium hydroxide), dehydrating agents (sulfuric acid, sodium hydroxide, phosphorus pentoxide, and calcium oxide), and oxidizing agents (hydrogen peroxide, chlorine, and bromine). Symptoms of exposure for inhalation include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea, and vomiting. For eyes, symptoms include pain, blood shot eyes, tearing, and blurring of vision. For skin, symptoms may include reddening, pain, inflammation, bleeding, blistering and burns. As a physical hazard, corrosive substances may corrode materials they come in contact with and may be highly reactive with other substances. It is important to review information regarding materials they corrode, and their reactivity with other substances, as well as information on health effects.

## **2.3. Irritants**

Irritants are defined as non-corrosive chemicals that cause reversible inflammatory effects on living tissue by chemical action at the site of contact. A wide variety of organic and inorganic compounds, including many chemicals that are in a powder or crystalline form, are irritants and consequently, skin contact with all laboratory chemicals should always be avoided.

## **2.4. Sensitizers**

A sensitizer (allergen) is a substance that causes exposed people to develop an allergic reaction in normal tissue after repeated exposure to the substance. Examples of allergens include diazomethane, chromium, nickel, formaldehyde, isocyanates, arylhydrazines, benzylic and allylic halides, and many phenol derivatives.

## **2.5. Flammable, Highly Reactive and Explosive Substances**

A number of highly flammable substances are in common use in campus laboratories. Highly Reactive substances are materials that decompose under conditions of mechanical shock, elevated temperature, or chemical action, with the release of large volumes of gases and heat. Some materials, such as peroxide formers, may not be explosive, but may form into substances that will deflagrate or explode.

Explosives are any chemical compound, mixture or device, the primary or common purpose of which is to function as by explosion; i.e., with substantially instantaneous release of gas or heat. The term includes, but is not limited to, dynamite and other high explosives, black powder, pellet powder, initiating explosives, detonators, safety fuses, squibs, detonating cord, igniter cord, and igniters. The possession or use of explosive materials are highly regulated by federal and state agencies, contact the EHS office 617-452-3477 for assistance before contemplating use. For the list of Alcohol, Tobacco and Firearms (ATF) explosive materials see <http://cryptome.org/2013/10/atf-13-1028.htm>

## **2.6. Hazardous Substances with Toxic Effects on Specific Organs**

Substances included in this category include (a) hepatotoxins (substances that produce liver damage such as nitrosamines and carbon tetrachloride); (b) nephrotoxins (agents causing damage to the kidneys such as certain halogenated hydrocarbons); (c) neurotoxins (substances which produce their primary toxic effects on the nervous system such as mercury, acrylamide, and carbon disulfide); (d) agents which act on the hematopoietic system (such as carbon monoxide and cyanides which decrease hemoglobin function and deprive the body tissues of oxygen); and (e) agents which damage lung tissue such as asbestos and silica.

## **2.7. Particularly Hazardous Substances/Select Carcinogens**

As discussed in earlier sections of this Chemical Hygiene Plan, hazardous chemicals are chemicals for which there is scientific evidence that adverse acute or chronic health effects may occur in exposed workers. An agent is an acute toxin if its toxic effects are manifested after a single or short-duration exposure. Chronically toxic agents show their effects after repeated or long-duration exposure and the effects usually become evident only after a long latency period. Many of the substances in frequent use in laboratories are classified as hazardous substances, and the procedures for working with these chemicals are detailed in Part II Section 3.1. and 3.2. There are some substances, however, that pose such significant threats to human health that they are classified as "particularly hazardous substances" (PHSs). The OSHA Laboratory Standard requires that special provisions be established to prevent the harmful exposure of researchers to PHSs. General procedures for working with such materials are presented in detail in Section 3.3.

For information and a list of PHSs, see <https://ehs.mit.edu/chemical-safety-program/dangerous-highly-toxic-chemicals/>

Chemicals are classified as *particularly hazardous substances* if they belong to one or more of the following three categories. Compounds classified as *particularly hazardous substances* generally must then be handled using the procedures outlined in Part II. Section 3.3 **in addition to** the procedures outlined for hazardous chemicals in Part II. Section 3.1 and 3.2. Appendix II. C. provides procedures to assist you in how to determine if a chemical is a particularly hazardous substance, as well as additional information on PHSs.

#### **2.7.1 Select Carcinogens**

Certain potent carcinogens are classified as "select carcinogens" and treated as PHSs. A select carcinogen is defined in the OSHA *Laboratory Standard* as a substance that meets one of the following criteria:

- a) It is regulated by OSHA as a carcinogen,
- b) It is listed as "known to be a carcinogen" in the latest Annual Report on Carcinogens published by the National Toxicology Program (NTP),
- c) It is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer (IARC), or
- d) It is listed under IARC Group 2A or 2B, ("probably carcinogenic to humans") or under the category "reasonably anticipated to be a carcinogen" by the NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria: (i) after inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m<sup>3</sup>; (ii) after repeated skin application of less than 300 mg/kg of body weight per week; or (iii) after oral dosages of less than 50 mg/kg of body weight per day.

The following Table on the next page lists the substances meeting criteria (a), (b), or (c). For information on compounds meeting criteria (d), examine IARC Group 2A and 2B lists and the NTP lists that are available on the Internet. See Appendix II-C for more information on PHSs.

#### **Partial List of Select Carcinogens (Includes OSHA Carcinogens)**

2-acetylaminofluorene	dimethyl sulfate
acrylamide	ethylene dibromide
acrylonitrile	ethylene oxide
4-aminodiphenyl	ethylenimine
arsenic and certain arsenic compounds	formaldehyde
asbestos	hexamethylphosphoramide
azathioprine	hydrazine
benzene	melphalan
benzidine	4,4'-methylene-bis(2-chloroaniline)
bis(chloromethyl) ether	methylene chloride
1,3-butadiene	methylene dianiline
1,4-butanediol dimethylsulfonate (myleran)	mustard gas
cadmium	N,N'-bis(2-chloroethyl)-2-naphthylamine (chlornaphazine)
chlorambucil	alpha-naphthylamine
chloromethyl methyl ether	beta-naphthylamine
chromium and certain chromium compounds	nickel carbonyl
coal-tar pitches	4-nitrobiphenyl
coal tars	N-nitrosodimethylamine
coke oven emissions	beta-propiolactone
conjugated estrogens	thorium dioxide
cyclophosphamide	treosulphan
1,2-dibromo-3-chloropropane	vinyl chloride
3,3'-dichlorobenzidine (and its salts)	
diethylstilbestrol	
dimethylaminoazobenzene	

Note: the above list is not intended to be complete, and it is the responsibility of the researcher (in consultation with their laboratory supervisor) to evaluate each compound involved in their work and to determine whether it should be handled as a select carcinogen.

### 2.7.2 Reproductive and Developmental Toxins

Reproductive toxins can affect the reproductive health of both male and female employees and students if proper procedures and controls are not used. For women, exposure to reproductive toxins during pregnancy can cause adverse effects on the fetus; these effects include embryoletality (death of the fertilized egg, embryo or fetus), malformations (teratogenic effects), and postnatal functional defects. Examples of embryotoxins include thalidomide and certain antibiotics such as tetracycline. Women of childbearing potential should note that embryotoxins have the greatest impact during the first trimester of pregnancy. Because a woman often does not know that she is pregnant during this period of high susceptibility, special caution is advised when working with all chemicals, especially those rapidly absorbed through the skin (e.g., formamide). Researchers who are pregnant or intending to become pregnant should arrange for a confidential consultation with MIT Medical. They should also consult with their laboratory supervisor and the Environment, Health and Safety (EHS) Office before working with substances that are suspected to be reproductive toxins. As minimal precautions, the general procedures outlined in Part II, Section 3.3 below should then be followed for work with such compounds. For men, the effects of certain reproductive toxins may include decline in fertility, malformations in off-spring, and certain types of cancer. Therefore, adequate protection from exposure must be employed.

Information on reproductive toxins can be obtained from Safety Data Sheets, by contacting the EHS Office Industrial Hygiene Program (617-452-3477).

The following Table lists some common materials that are suspected to be reproductive toxins; in most laboratories it will be appropriate to handle these compounds as *particularly hazardous substances*.

### Partial List of Reproductive Toxins

arsenic and certain arsenic compounds	lead compounds
benzene	mercury compounds
cadmium and certain cadmium compounds	toluene
carbon disulfide	vinyl chloride
ethylene glycol monomethyl and ethyl ethers	xylene
ethylene oxide	

Note: The above list is not intended to be complete, and it is the responsibility of the researcher (in consultation with their laboratory supervisor) to evaluate each compound involved in their work and to determine whether it should be handled as a reproductive toxin.

### 2.7.3 Compounds with a High Degree of Acute Toxicity

Compounds that have a high degree of acute toxicity comprise a third category of *particularly hazardous substances* as defined by the OSHA *Laboratory Standard*. Acutely toxic agents include certain corrosive compounds, irritants, sensitizers (allergens), hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic systems, and agents which damage the lungs, skins, eyes, or mucous membranes. Substances that have a high degree of acute toxicity are interpreted by OSHA as being substances that "may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration".

#### Toxic and Highly Toxic Agents

OSHA regulations (29 CFR 1910.1200 Appendix A) define toxic and highly toxic agents as substances with median lethal dose (LD<sub>50</sub>) values in the following ranges:

Test	Toxic	Highly Toxic
Oral LD <sub>50</sub> (albino rats)	50-500 mg/kg	<50 mg/kg
Skin Contact LD <sub>50</sub> (albino rabbits)	200-1000 mg/kg	<200 mg/kg
Inhalation LC <sub>50</sub> (albino rats)	200-2000 ppm/air	<200 ppm/air

It is important to note that the above classification does not take into consideration *chronic toxicity* (e.g. carcinogenicity and reproductive toxicity). Also, note that LD<sub>50</sub> values vary significantly between different species, and the human toxicity for a substance may be greater or less than that measured in test animals. OSHA considers substances that are either toxic or highly toxic, as defined above, to be *particularly hazardous substances*.

In evaluating the acute toxicity of chemical substances, the HMIS (Hazardous Materials Identification System) rating criteria developed by the National Paint and Coatings Association may be helpful. HMIS numbers can often be found in SDSs. LD<sub>50</sub> values can be found in SDSs and in references such as the *Sigma-Aldrich Library of Chemical Safety Data* and Patnaik's *A Comprehensive Guide to the Hazardous Properties of Chemical Substances*.

The following Table lists some of the compounds that may be in current use in campus laboratories and that have a high degree of acute toxicity:

#### Partial List of Compounds with a High Degree of Acute Toxicity

abrin	nitrogen dioxide
acrolein	osmium tetroxide
Arsine	Ozone
Chlorine	phosgene
Diazomethane	Ricin
diborane (gas)	sodium azide
hydrogen cyanide	sodium cyanide (and other cyanide salts)
hydrogen fluoride	Strychnine
methyl fluorosulfonate	
nickel carbonyl	

Note: the above list is not intended to be complete, and it is the responsibility of the researcher (in consultation with their laboratory supervisor) to evaluate each compound involved in their work and to determine whether it is a substance with a high degree of acute toxicity.

Compounds classified as having a high degree of acute toxicity must generally be handled using the procedures outlined in Part II. Section 3.3 below in addition to the procedures outlined for hazardous chemicals in Part II. Section 3.1 and 3.2. Finally, several of the compounds listed may require prior approval from the DLC EHS Committee before work with them can be carried out. See Part IV. Section 2. for a discussion of prior approval requirements.

In evaluating the hazards associated with work with toxic substances, it is important to note that a number of factors influence the response of individuals to exposure to toxic compounds. For example, people are rarely exposed to a single biologically active substance. With this point in mind, it is noteworthy that one toxin can influence the effect of a second. This underscores the importance of maintaining good laboratory practices at all times, and with all chemicals.

## 2.8 Green Chemistry

Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products. Use the 12 Principles of Green Chemistry to design or modify experiment to make it more environmentally friendly and sustainable. Consider waste and hazard prevention during design, rather than disposing, treating and handling waste after a processor material has been developed. For more information on Green Chemistry and the 12 Principles, visit the EHS Office website at <https://ehs.mit.edu/green-chemistry/>.

### 12 Principles of Green Chemistry:

- 1. Prevent waste:** Design chemical syntheses to prevent waste. Leave no hazardous or toxic waste.
- 2. Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.
- 3. Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.
- 4. Design safer chemicals and products:** Design chemical products that are fully effective yet have little or no toxicity.
- 5. Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.
- 6. Increase energy efficiency:** Run chemical reactions at room temperature and pressure whenever possible.
- 7. Use renewable feedstocks:** Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural

- products or the wastes of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.
8. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
  9. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.
  10. **Design chemicals and products to degrade after use:** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
  11. **Analyze in real time to prevent pollution:** Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
  12. **Minimize the potential for accidents:** Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

### 3. STANDARD OPERATING PROCEDURES FOR WORK WITH HAZARDOUS CHEMICALS

#### 3.1. Preliminary Steps and Procedures

All work involving chemicals in MIT laboratories must be conducted using the “Standard Operating Procedures” outlined below. In addition, laboratory workers must determine whether any of the chemicals to be handled in the planned experiment meet the definition of a particularly hazardous substance (PHS) due to high acute toxicity, carcinogenicity, and/or reproductive toxicity (PHS definition refer to Part II 2.7 p.15) by:

1. Performing a check to see if the chemical(s) meets the definition and is on the PHS list <https://ehs.mit.edu/chemical-safety-program/dangerous-highly-toxic-chemicals/>. If your chemical(s) is not listed it should still be evaluated for high acute toxicity, carcinogenicity, and/or reproductive toxicity. For more guidance on how to determine if a chemical is a PHS see Part II 10.3 Appendix IIC p.40.
2. If listed or determined to be a PHS chemical then do a risk assessment to see if there are any procedures or protective measures “beyond” those already required for hazardous chemicals outlined in this section. Consider the total amount of the substance that will be used, the expected frequency of use, the chemical's routes of exposure, and the circumstances of its use in the proposed experiment.
3. If it is determined that the PHS requires additional protective measures they can be found in Part II section 3.3 p. 27.
4. If the chemical is not listed or determine to be a PHS or does not require additional protective measures then follow the procedures for Hazardous Chemicals outlined in this section.

For very toxic or hazardous substances, or specialized practices, consideration must be given to whether additional consultation with safety professionals and development of Lab Specific SOPs is warranted or required. EHS or the EHS Coordinators/Chemical Hygiene Officer may decide if the lab should develop additional SOPs for PHSs. **NOTE:** Additional consideration should be given to laboratory operations involving hazardous substances that are sometimes carried out continuously or overnight. It is the responsibility of the researcher to design these overnight experiments with provisions to prevent the release of hazardous substances in the event of interruptions in utility services such as electricity, cooling water, and inert gas. Laboratory lights should be left on and appropriate signs should be posted on the entrance door(s) as well as near the experiment identifying the nature of the experiment and the hazardous substances in use. In some cases, arrangements should be made for periodic inspection of the operation by other workers. Information should be posted on the signs indicating how to contact you in the event of an emergency.

**STEP 1: Determine the toxicity and warning properties of the chemicals to be used in your experiment.**

- ❑ Identify the chemicals involved in the proposed experiment and determine the amounts that will be used.
- ❑ Use an up-to-date LCSS or SDS to determine the exposure limit, type of toxicity, warning properties (smell, irritation, etc.) and symptoms of exposure for each chemical involved in the planned experiment.
- ❑ If a new chemical substance(s) will be produced during the experiment and the toxicity is unknown, assume it is a particularly hazardous substance and follow the procedures in Part II. Section 3.3.
- ❑ Assume that any mixture of chemicals will be more toxic than its most toxic component.
- ❑ Consider substituting less toxic chemicals. Find the resources for greener chemical alternatives at the EHS Office website <https://ehs.mit.edu/greener-chemistry/>.

**STEP 2: Determine most likely routes of exposure based on how chemicals will be used and their physical/chemical properties.**

- ❑ **Inhalation** – Inhalation risks are highest when volatile liquids, gases, dusts, or mists are used or generated. Heating will increase the volatility of liquids. Pay particular attention to chemicals with low exposure limits. Potential for inhalation is highest when chemicals are used on an open lab bench. Use in enclosed apparatus or chemical laboratory hoods decreases inhalation exposure potential.
- ❑ **Skin Exposure** – Chances for skin exposure exist for most laboratory chemical procedures. When the “skin” notation is listed in the exposure limit section of the SDS, the chemical can be absorbed through the intact skin.
- ❑ **Injection or ingestion** – Not normally a major route of exposure if proper handling procedures are used. Determine whether the experiment involves a significant risk of inadvertent ingestion or injection of chemicals.

**STEP 3: Determine required control measures, personal protective equipment, and proper work practices to minimize exposure.**

**A. Inhalation Control Measures**

**Determine When to Use Laboratory Chemical Hoods (Fume Hoods)**

Procedures involving volatile toxic substances and those operations involving solid or liquid toxic substances that may result in the generation of vapors or aerosols should be conducted in a laboratory hood or other type of local exhaust ventilation. See Part II. Section 5. for a more detailed discussion of laboratory hoods. Other types of control devices include glove boxes, custom designed hoods, shut-off valves, and monitoring equipment linked to alarms and shut-off valves.

**Determine Whether Respirators Might Be Required**

Generally, hazards should be controlled by use of ventilation and it should not be necessary to use respirators. Contact the Industrial Hygiene Program for help in evaluating the need for a respirator. If one is needed and you are medically qualified to wear a respirator, obtain one of the correct type and size from the Industrial Hygiene Program. A respirator will be provided at no charge to employees and researchers if one is needed to keep their exposure below applicable PELs". Do not use a lab mate's respirator. The MIT Respirator Protection Program is described in full at <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/>

**B. Personal Protective Equipment For Eyes and Skin**

*Note: More details regarding (list DLC here) policy for use of eye protection in the laboratory is found in section 4.2 below.*

Select and wear appropriate eye and face protection. Wearing eye protection is required by OSHA regulation whenever and wherever potential eye hazards exist. Hazards requiring eye and/or face protection include flying particles; molten metal; liquids including acids and caustic materials,

biological or radioactive materials; chemical gases or vapors; and potentially injurious light radiation. Many Departments, Labs and Centers require eye protection at all times in labs and shops, and post “eye protection required” signs on the doors or in the hazardous areas. Use safety glasses with side shields as basic eye protection for handling chemicals where there is a low risk of splash or splatter. When pouring large amounts of chemicals, observing processes that are under heat or pressure, making adjustments to chemical containing apparatus, or performing other operations or tasks with a moderate to high potential splash risk or severe consequences in the event of a splash, chemical goggles should be used. A face shield can be used with the goggles to protect the face under these circumstances.

Wear appropriate clothing when in the laboratory. The minimum requirements that apply to any spaces that fall under this DLC CHP are outlined in the table below. Note that specific labs or DLCs may have stricter requirements. In some cases, through a hazard assessment, laboratory supervisors may identify situations (a task, experiment, or area) where alternative or more protective apparel must be worn. Refer to section 4 and to <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/> for more detailed information on PPE assessments, selection and use.

Minimum Requirements	Activity			Details
	Brief lab visit or walk-through*	Not Working With or Nearby to Chemicals, BL2 Materials, or Radioactive Materials **	Working With or Nearby to Chemicals, BL2 Materials, or Radioactive Materials***	
Shoes that fully cover the feet.	Required	Required	Required	<ul style="list-style-type: none"> <li>• Never wear open toe or open heel shoes such as flip-flops or sandals.</li> <li>• High heeled shoes or flats that leave the top of the foot exposed should not be worn.</li> <li>• Shoes made of porous materials such as mesh or fabric provide only limited protection in a spill and should be avoided when working with materials that can become a spill hazard.</li> </ul>
Clothing that covers the legs	Recommended	Required	Required	<ul style="list-style-type: none"> <li>• When required, the combination of shoes and clothing must provide full coverage of feet and legs.</li> <li>• Thin or tight leg coverings, such as tights, should be avoided when working with materials that can become a spill hazard.</li> <li>• Synthetic materials such as spandex, nylon, and polyester can melt to the skin when heated and should not be worn when there is a significant fire hazard.</li> </ul>



Lab coat	Recommended; DLC/Lab Dependent	Recommended; DLC/Lab Dependent	Required	<ul style="list-style-type: none"> <li>• Lab coat material should be chosen based on a hazard assessment.</li> <li>• Flame resistant lab coats are required when handling pyrophoric materials.</li> <li>• Comparable protective measures may be used in place of a lab coat depending on special research needs. These alternatives must be reviewed with the DLC EHS Coordinator.</li> </ul>
Gloves			DLC/Lab/Activity Dependent	<ul style="list-style-type: none"> <li>• Appropriate gloves chosen based on hazards and compatibility.</li> </ul>
Eye protection and other PPE	DLC/Lab Dependent	DLC/Lab Dependent	DLC/Lab/Activity Dependent	<ul style="list-style-type: none"> <li>• Eyewear requirements based on DLC/lab policies and hazard assessments.</li> <li>• Other PPE may be required depending on PPE hazard assessment for the lab or DLC.</li> </ul>

\* This category includes people that will only be in a lab space briefly, including but not limited to delivery personnel, MIT students and employees going through a space but not stopping to work, and tour participants. Visitors will not spend time observing or standing near areas where active work with chemicals, biologicals, radioactive materials, lasers, or other potential hazards are being used.

\*\* This category includes but is not limited to those at desks or office areas within labs that are away from active work areas and those that are using equipment where there are no chemicals or other hazards.

\*\*\* This category includes those working with hazardous materials as well as those working nearby to those materials where there is an expected risk of exposure. People working at desks may fall under this category depending on the activities happening around the desk. Ultimately it is the responsibility of the PI to assess the hazards around desk areas and determine if lab coats or other PPE are required due to the proximity of hazardous materials or processes.

**Table Instructions:**

*DLC EHS Coordinator and/or CHO should enter any DLC-specific PPE requirements in the table above. DLC-specific requirements must be at least as stringent as the requirements listed in the table.*

A combination of clothing and shoes that fully cover the legs and feet is required when working in spaces that have hazardous chemicals, which includes almost all lab spaces. Similarly, there are requirements to have the legs covered in spaces with other hazards that could pose a risk to individuals, such as physical hazards or biological and radioactive materials that pose an exposure risk. Individuals briefly visiting a space are exempt from this requirement if they are not near hazardous materials.

(Insert DLC name) has an exemption process for low-risk rooms or areas within rooms where less stringent clothing requirements may be acceptable based on a hazard assessment. Requests must be made by the PI or Supervisor in charge of the area in writing and are reviewed by (insert the role(s) of the person(s) that review and approve). In shared spaces all PIs and/or Supervisors that oversee the space must be included in the request.

Approved exemptions are documented by the Materials Research Laboratory and the EHS Office and reviewed if hazards in the space change. Information on clothing requirements is to be included in the lab specific training given to the users of each space where an exemption has been granted.

**Exemption Instructions:**

*The CHP template wording regarding clothing exemptions must be modified when incorporated into DLC-specific CHPs to reflect how this will be implemented within the DLC. If exemptions will not be allowed in the DLC remove the CHP template language mentioning the exemption process. Refer to the “Clothing Exemptions – Guiding Principles” document at <https://ehs.mit.edu/chemical-safety-program/chemical-hygiene/> for guidance on setting up a DLC exemption process.*

Avoid skin contact and ingestion of hazardous substances by using appropriate hand protection, protective clothing, and proper work practices.

Contact with the skin is a frequent mode of chemical injury. A common result of skin contact is localized irritation, but an appreciable number of hazardous substances are absorbed through the skin with sufficient rapidity to produce systemic poisoning. Ingestion of substances is rarely deliberate, but may occur because of contamination of hands handling food, contamination of common work surfaces in the lab, and incidental contamination of food or materials that come in contact with the mouth, and through poor work practices. Avoid contact with, and ingestion of, hazardous substances by taking the following precautions:

- ❑ Select and wear appropriate hand protection, generally gloves, to prevent injury to hands or exposure by absorption of chemicals through the skin of the hands. **See details on glove selection in Section 4.**
- ❑ Never use mouth suction to pipette chemicals or to start a siphon; a pipette bulb or aspirator should instead be used to provide vacuum.
- ❑ Never taste laboratory chemicals.
- ❑ Wash your hands with soap and water immediately after working with hazardous chemicals.
- ❑ Eating, drinking, smoking, gum-chewing, and applying cosmetics in laboratories where hazardous substances are in use is prohibited. Do not store food, beverages, cups, or other drinking and eating utensils in areas where hazardous chemicals are used or stored.
- ❑ Immediately clean up small spills on work benches or in laboratory hoods.

**Properly use and maintain personal protective equipment (PPE).**

Personal protective equipment should be kept clean and stored in an area where it will not become contaminated. Personal protective equipment should be inspected prior to use to be sure it is in good condition. It should fit properly and be worn properly. If it becomes contaminated or damaged, it should be cleaned or fixed or, in the case of disposable equipment, discarded and replaced.

For additional requirements and information on selection of PPE, see Part II. Section 4. and visit the EHS Office website at <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/>

**STEP 4: Be Prepared for Emergencies**

Before beginning an experiment, know what specific action you will take in the event of the accidental release of any hazardous substances involved. Know the location and how to operate eye washes, safety showers, spill carts and spill control materials. Be familiar with the location of the nearest fire alarm and telephone, and know what telephone numbers to call in the event of an emergency. Know the

location of the circuit breakers for your laboratory. For information on fire blankets see <https://ehs.mit.edu/workplace-safety-program/fire-safety/>

**For all accidents requiring emergency police, fire, or medical response, contact Campus Police at 617-253-1212 or 100 from an MIT telephone.**

An *MIT Emergency Response Guide* should be posted in every laboratory in an area accessible to all. This guide outlines the procedures to follow for most types of emergency situations. The MIT Emergency Response Guide is available electronically at <https://ehs.mit.edu/about/emergency-management/> Carefully review the guidelines for handling medical emergencies, personal injury, chemical spills and fire in the laboratory. This information could save you or your lab mate's life. Only a subset of that information is repeated here.

### Fire

If the fire alarms are ringing in your building, stop what you are doing, leave all belongings and immediately proceed to the nearest, safe building exit. Many buildings have evacuation diagrams in strategic building locations. You can always follow the illuminated exit signs when evacuating a building unfamiliar to you. As you leave the building, close doors behind you and use the stairs - do not take elevators.

Once outside proceed directly to your designated assembly area watching out for emergency vehicles that may be responding. Your supervisor will inform you where your assembly area is located and your primary and secondary evacuation route. You must remain in the assembly area until the "All Clear" has been communicated. DO NOT re-enter your work area until given the "All Clear."

A floor plan showing Building 13 emergency exits, fire alarm pull stations, emergency showers, fire extinguishers, evacuation instruction, and other important information is posted on each floor opposite the passenger elevators. We encourage you to become familiar with the locations of the fire/emergency alarm pull stations on your floor. Building 13 has four emergency Egress Stairwells: The north stairwells (the even-numbers side, facing Vassar Street) are located at the center of the building, and at the east end. The south stairwells (the odd-numbers side, facing the Charles River) are located at the west end of the building, and behind the passenger elevators. All stairwells are identified with lighted "Exit" signs. Persons with ambulatory difficulties should use horizontal evacuation from the west end of Building 13 (into Building 9) on the second, third, and fourth floors, or horizontal evacuation from the south east end of Building 13 on the fourth and fifth floors (into Building 10).

<u>Dial 100 for: Life Threatening Situations</u>	<u>Dial Customer Service 3-4948 (fixit) for:</u>
Ambulance	City gas leaks
Accidents	Stuck elevators
Fire	Floods
Police	Loss of heating
Serious illness	Loss of fume hood fans or ventilation
Toxic gas leaks	Loss of electricity

To summon emergency police, fire, or ambulance assistance, call the Campus Police 24-hour line **100**. Report the location of the emergency, including both your building and room number. Be as specific as possible about the nature of the emergency and the type of assistance required. By clearly describing the nature of the situation, you can ensure an appropriate response. In the event of uncertainty, Campus Police are instructed to order a "full-force" response!

Notify other workers in the area of the nature of the emergency. If necessary, activate the fire alarm to order the evacuation of the building. **When the fire alarm sounds, all personnel, without exception, are required to leave the building.** Evacuate using the doors labeled "Exit"; do not use elevators. Emergency Action Floor Plans are posted on every floor of the building and show the location of exits, evacuation routes, and fire alarm pull stations. After evacuating the building, assemble in the designated meeting area (generally in front of the building).

In the event of fires, explosions, and releases of hazardous materials, a **Fire or Incident Command Post** marked with colored plastic posts and signs will be set up at the scene by the MIT emergency responders. The MRL EHS Coordinator or the MRL Chemical Hygiene and Safety Officer and the MIT official coordinating the emergency response ("Incident Commander") will be found at this post. Personnel from the laboratory involved in the accident should contact this official to provide information and technical assistance. The Incident Commander will also serve as liaison for communicating information to the Cambridge Fire Department and MIT Campus Police. Fire Department and Police personnel will generally not follow instructions from MIT students and faculty unless authorized by the Incident Commander.

### **SEL – Substrate Engineering Laboratory**

**Room 13-1150** is a lab used for the epitaxial growth of novel silicon germanium and gallium arsenide based photonic devices. This laboratory stores and uses a variety of toxic precursor gases. Every effort has been made to ensure that this laboratory is a safe addition to Building 13 and the MIT community.

This laboratory utilizes a 4-lamp signal tower to indicate different states of operation:

- Green**– Normal operation, all systems operating normally
- White**– System trouble, alert. Lab personnel investigate system troubles.
- Yellow**– Trace amounts of toxic gas detected *within the laboratory equipment*.
- Blue**– Trace amounts of gas are detected *within the laboratory*.

When the gas monitoring system detects possible trace amounts of **toxic gas inside the lab equipment**:

- The yellow lights begin flashing (This is simply an alert to the research group to investigate.)

When the gas monitoring system detects possible trace amounts of **toxic gas in the laboratory**:

- The blue lights begin flashing
- The lab is evacuated until the alarm source is pinpointed, but there is no danger to people outside of the lab.
- No one is allowed in the lab without self-contained breathing apparatus

When the gas monitoring system detects **two or more possible trace amounts of toxic gas in the laboratory**:

- The blue lights begin flashing
- The fire/emergency alarm is triggered (The building is evacuated as a safety precaution; there is no way for the toxic gas to escape from the lab.)
- No one is allowed in the laboratory without self-contained breathing apparatus

With any alarm, all toxic gas tanks are automatically shut off at their sources by electronic relays. These relays also close if power is lost to the lab. This prohibits gas use if the safety monitoring system is disabled. Note that false alarms at all levels are possible. All alarms, however, are treated as real until proven otherwise.

### **Jaramillo Lab**

**Room 13-5141** is a lab used for epitaxial growth of novel silicon germanium and gallium arsenide-based semiconductors. This laboratory stores and uses a variety of toxic precursor gasses. Every effort has been made to ensure that this laboratory is a safe addition to Building 13 and the MIT Community.

When the gas monitoring system detects possible trace amounts of **toxic gas inside the laboratory equipment**:

- The amber lights begin flashing (This is simply an alert to the research group to investigate.)

When the gas monitoring system detects possible trace amounts of **toxic gas in the laboratory**:

- The blue lights begin flashing (The lab should be evacuated until the alarm source is pinpointed, but there is no danger to people outside of the lab.)

When the gas monitoring system detects **1 TLV levels of trace amounts of toxic gas in the laboratory:**

- The blue lights begin flashing
- The fire/emergency alarm is triggered (The building is evacuated as a safety precaution, there is no way for the toxic gas to escape from the lab.)

With any alarm, all toxic gas tanks are automatically shut off at their sources by electronic relays. These relays also close if power is lost to the lab. This prohibits gas use if the safety monitoring system is disabled. Note that false alarms at all levels are possible. All alarms, however, are treated as real until proven otherwise.

### **Gradecak Lab**

**Room 13-5027** is a lab used for the growth of III-V compound semiconductor nanowires. The lab stores and uses several hazardous precursor gases and liquids. A great amount of effort has gone into designing the system in the safest manner possible.

A Toxic Gas Monitoring Control System has been installed to monitor the complete operation of the lab and alert people to detected hazards. The lights outside 13.5027 are used to communicate the current status of the MOCVD to residents of building 13, in combination with possible audible alarms.

How to interpret the 4-lamp signal tower:

□ **Blue:** The emergency toxic gas alarm has been pulled or Silane is detected in the ambient atmosphere. If concentrations are > 0.5 TLV the **global toxic gas alarm** will also be triggered (see below).

• **Amber:** Silane is detected within a contained, vented enclosure. If concentrations are > 0.5 TLV the global toxic gas alarm will also be triggered (see below). The local lab alarm will be triggered if concentrations are <0.5 ppm.

• **White:** Maintenance issue with the MOCVD, no hazards present. Local equipment alarm may be audible.

• **Green:** Normal operation, system OK.

\*TLV is the threshold limit value, the airborne concentration to which a worker can be exposed to this material for 40hrs/wk for their entire working life without adverse health affects.

How to interpret the audible alarms:

• **Global Toxic Gas Alarm:** This is **the only alarm that requires immediate response** from personnel outside of the lab. If you hear a building wide alarm announcing a “toxic gas alarm” then you should immediately evacuate the building.

• **Local Lab Alarm:** This alarm sounds like a car horn. It indicates hazards within 13-5027 that are not a threat outside the lab. This alarm requires only lab evacuation; you do not need to evacuate the building.

• **Local Equipment Alarm:** These alarms come from instruments in the lab. They indicate that necessary conditions for reactor operation are not being met but no hazards are present.

With any alarm, all toxic gas tanks are automatically shut off at their sources by electronic relays. These relays also close if power is lost to the lab. This prohibits gas use if the safety monitoring system is disabled. Note that false alarms at all levels are possible. All alarms, however, are treated as real until proven otherwise.

### **Laboratory Emergency Information Cards**

Every laboratory door should be posted with an up-to-date green emergency information card that lists the names and telephone numbers (on how to reach them in the event of an emergency) of all personnel working in the laboratory. It is the responsibility of laboratory supervisors, with the assistance of the EHS representatives, to ensure that these cards are updated regularly. Blank cards can be obtained from MRL EHS Coordinator (13-2014).

#### **A. Chemical Contamination**

If the victim or their clothes are chemically contaminated, put on appropriate personal protective equipment and remove victim's contaminated clothing. Using a chemical shower, eyewash, or sink

in a safe area, *flood* contaminated body part(s) with *large amounts* of water for *15 minutes* and *seek medical assistance*.

## **B. Safety Data Sheets (SDS)**

As time permits, and if you will not be placed at risk, attempt to identify the chemicals involved and obtain SDS, or other relevant information. Provide the SDS to the ambulance crew.

## **C. Chemical Spills – Minor vs. Major**

Be prepared in advance. Have spill supplies available for the types of spills that might occur. Know under what circumstances you should clean up the spill, or when you should evacuate and seek help.

**Minor** hazardous materials or waste spills that present no immediate threat to personnel safety, health, or to the environment can be cleaned up by laboratory personnel that use the materials or generate the waste. A minor hazardous material spill is generally defined as a spill of material that is not highly toxic, is not spilled in large quantity, does not present a significant fire hazard, can be recovered before it is released to the environment, and is not in a public area such as a common hallway. Such a spill can usually be controlled and cleaned up by one or two personnel. **For assistance for the cleanup of minor spills call the EHS Office 617-452-3477 or nights and weekends the Facilities Operations Center 617-253-4948 or internally 3-4948 (fixit).**

**Major** hazardous material and waste spills should be reported to the MIT emergency number (617-253-1212, or 100 from an MIT telephone) to receive immediate professional assistance and support in the control and cleanup of the spilled material. Major hazardous materials or waste spills are generally defined as having a significant threat to safety, health, or the environment. These spills generally are a highly toxic material or a less toxic or flammable material spilled in a large enough quantity that may present a significant fire hazard, cannot be recovered before it is released to the environment, or is spilled in a public area such as a common hallway. Upon reporting such a spill personnel should stand-by at a safe distance to guide responders and spill cleanup experts to the spill area. Reporting personnel should also keep other personnel from entering into the spill area.

In the case of a spill that presents a situation immediately dangerous to life or health, or a situation with significant risk of a fire, personnel should evacuate the area and summon emergency assistance by dialing the MIT emergency number (617-253-1212, or 100 from an MIT telephone), activating a fire alarm station, or both.

## **3.2. Essential Laboratory Work Practices**

### **3.2.1. Properly use, maintain, and dispose of laboratory glassware and other sharps.**

Improper use of glassware is a frequent cause of injuries and accidents in the laboratory.

- Careful handling and storage procedures should be used to avoid damaging glassware. Always carefully inspect glassware for flaws and cracks before use. Damaged items should be discarded or repaired.
- Adequate hand protection should be used when inserting glass tubing into rubber stoppers or corks or when placing rubber tubing on glass hose connections. Tubing should be fire polished or rounded and lubricated, and hands should be held close together to limit movement of glass should fracture occur. The use of plastic or metal connectors should be considered.
- Glass-blowing operations should not be attempted unless proper annealing facilities are available.
- Vacuum-jacketed glass apparatus should be handled with extreme care to prevent implosions. Equipment such as Dewar flasks should be taped or shielded. Only glassware designed for vacuum work should be used for that purpose.

- ❑ Hand protection should be used when picking up broken glass. (Small pieces should be swept up with a brush into a dustpan).
- ❑ Broken glassware, syringes, and other "sharp objects" must be disposed of properly. Such waste should be separated from other trash and stored for pickup in clearly marked containers labeled "sharps". See Part II. Section 8. for more details on handling "sharps".

### 3.2.2. **Attend to housekeeping by establishing and following routine cleaning procedures as part of the work you do.**

There is a definite relationship between safety and orderliness in the laboratory. The following housekeeping rules should be adhered to in all laboratories:

- ❑ Clean bench tops and other work areas and equipment regularly. Do not allow dirty glassware, expired or unneeded samples or chemicals, and trash or boxes to accumulate. When floors require cleaning, notify building services.
- ❑ Maintain ready access to exits, safety equipment such as fire extinguishers, eyewashes, and safety showers and electrical panels. Do not store materials in a way that will block access to exits, safety equipment or electrical panels. **Maintain a minimum clearance of 36 inches in aisles between work benches and 44 inches in the main cross aisle of the lab that leads to the lab exit door. The main cross aisle is the aisle that all of the bench aisles intersect with to allow the occupants to follow the egress path to the exit door.**
- ❑ Ensure all compressed gas tanks are properly secured to walls or benches.
- ❑ Chemical storage refrigerators should be defrosted periodically and should not be overcrowded.
- ❑ Utilize proper cord management techniques so that cords do not get damaged or become tripping hazards.

### 3.2.3. **Working Alone**

As a practice, working alone with hazardous materials, equipment or otherwise working under conditions that may create the risk of serious injury (hereafter referred to as hazardous conditions) should be avoided.

Anyone at MIT (faculty, staff, students, and visitors) who works with (or intends to work with) potentially hazardous conditions (in any location, i.e. laboratories, shops, field work) that may result in immediate injury or serious harm must discuss this activity with their Principal Investigator (PI) or supervisor prior to conducting the work alone and determine that the risk of working alone is controllable under the specific conditions established by the PI or supervisor for the work. If the PI or supervisor determines that the risk cannot be minimized to a controllable level, then the individual should perform the work only when others are present or a suitable alarm device that is available that will summon help immediately.

Furthermore, **undergraduates** shall not work alone with hazardous materials, equipment or operations that can result in immediate injury or death without prior written approval from the immediate PI or supervisor. Written approval should only be granted after the risk assessment is performed and reviewed by the PI or supervisor with the individual. This policy states the minimum requirements for working alone across the Institute and supersedes any less restrictive policy or procedure.

Specific Working Alone policies from Institute Committees or individual DLCs or individual PIs or supervisors that are more restrictive shall take precedence.

Guiding Principles In Support of MIT's Working Alone Policy can be found on the EHS web site <https://ehs.mit.edu/about/policies/working-alone-policy/>

### 3.2.4. **Discourage children and pets in laboratories.**

Prudent safety practices discourage allowing children in laboratories where hazardous substances are stored or are in use. It is therefore urged that children not be permitted in laboratories. However, if children are allowed, they must be under the direct supervision of their parent or other qualified adult, and should be allowed to visit only for a brief period of time.

### **3.2.5. Establish and follow safe chemical storage procedures for your laboratory.**

Researchers should consult the Environment, Health and Safety (EHS) Office website for chemical storage information at: <https://ehs.mit.edu/chemical-safety-program/chemicals/> and the standard operating procedure (SOP) on Chemical Storage at <https://ehs.mit.edu/sops/> (certificate login is required) for a discussion of procedures for storing chemicals in laboratories. All procedures employed must comply with OSHA, flammable material, and building code regulations. The following minimum guidelines must be adhered to:

- ❑ Access to all hazardous chemicals, including toxic and corrosive substances, should be restricted at all times. Specifically, good practice would dictate that these materials be stored in laboratories or storerooms that are kept locked at all times when laboratory personnel are not present. In the case of unusually toxic or hazardous materials, additional precautions are advisable and likely required, such as keeping the materials in locked storage cabinets. Contact the EHS Office to determine the appropriate controls.
- ❑ To avoid the accumulation of excess chemicals, it is recommended that you review the lab's chemical inventory prior to purchasing new chemicals. When purchasing new chemicals, purchase the minimum quantities of commercial chemicals necessary for your research.
- ❑ Make sure all containers of chemicals are in good condition.
- ❑ Make sure all containers of chemicals, (including research samples), are properly labeled. When appropriate, special hazards should be indicated on the label. For certain classes of compounds, (e.g. ethers), the date the container was opened should be written on the label. More guidance on labeling is provided in Part II. 6.
- ❑ Store incompatible materials in separate cabinets. If they must be stored together due to space limitations, provide secondary containment to separate incompatible materials.
- ❑ Do not store hazardous liquids above eye-level. Particularly, large containers (more than 1 liter) should be stored below eye-level on low shelves. Avoid storage of hazardous chemicals on the floor. If such storage is required, provide secondary containment for liquids stored on the floor.
- ❑ For refrigerated storage of chemicals, ensure refrigeration equipment is selected properly for the types of materials to be stored. Temperature-sensitive, flammable chemicals with a flashpoint of 140 °F or less (GHS flame pictogram) must be stored in a refrigerator/freezer that has a spark free interior and that is UL, FM or other NRTL approved for flammable storage. The sparks from the components in a household-type refrigerator/freezer could ignite flammable vapors and cause a fire or explosion. For more details, refer to <https://ehs.mit.edu/chemical-safety-program/chemicals/>. Food should never be kept in refrigerators used for chemical storage.
- ❑ Do not store flammable, volatile toxic, or corrosive chemicals in cold rooms.
- ❑ Do not store items in the working space of fume hoods.

### **3.2.6. Take precautions when transporting hazardous substances between laboratories.**

Chemicals must be transported between stockrooms and laboratories in break-resistant or approved secondary containers. Approved secondary containers are defined as commercially available bottle carriers made of rubber, metal, or plastic, with carrying handle(s), and which are large enough to hold the contents of the chemical container in the event of breakage. When transporting cylinders of



compressed gases, always strap the cylinder in a suitable hand truck and protect the valve with a cover cap. For shipping hazardous materials off-site, please refer to Part II. Section 9.

**3.2.7. Follow established procedures for handling excess and waste chemicals to ensure compliance with regulatory requirements.**

Consideration of the means of disposal of chemical wastes should be part of the planning of all experiments before they are carried out. The cost of disposing of excess and waste chemicals has become extremely expensive, and frequently exceeds the original cost of purchasing the chemical. Whenever practical, order the minimum amount of material possible in order to avoid the accumulation of large stocks of "excess chemicals" which will not be needed in future research. Such collections of "excess chemicals" frequently constitute safety hazards since many substances decompose upon long storage and occasionally their containers become damaged or degrade. In addition, the disposal of significant quantities of excess chemicals ultimately presents a very significant financial burden to faculty research accounts.

The procedures for handling excess and waste chemicals are outlined in Part II. Section 8.

**3.2.8. Take additional precautions for work with flammable substances.**

Flammable substances are among the most common of the hazardous materials found in campus laboratories. Flammable substances are materials that readily catch fire and burn in air. A flammable liquid does not itself burn; it is the vapors from the liquid that burn. The rate at which different liquids produce flammable vapors depends on their vapor pressure, which increases with temperature. The degree of fire hazard depends also on the ability to form combustible or explosive mixtures with air, the ease of ignition of these mixtures, and the relative densities of the liquid with respect to water and of the gas with respect to air.

An open beaker of diethyl ether set on the laboratory bench next to a Bunsen burner will ignite, whereas a similar beaker of diethyl phthalate will not. The difference in behavior is due to the fact that the ether has a much lower flash point. The flash point is the lowest temperature, as determined by standard tests, at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid within the test vessel. As indicated in the following table, many common laboratory solvents and chemicals have flash points that are lower than room temperature and are potentially very dangerous.

	Flash Point (°C)		Flash Point (°C)
Acetone	-17.8	Ethanol	12.8
Benzene	-11.1	Hexane	-21.7
Carbon disulfide	-30.0	Methanol	11.1
Cyclohexane	-20.0	Pentane	-40.0
Diethyl ether	-45.0	Toluene	4.4

**Precautions for handling flammable substances include:**

- Flammable substances should be handled only in areas free of ignition sources. Besides open flames, ignition sources include electrical equipment (especially motors), static electricity, and for some materials, (e.g. carbon disulfide), even hot surfaces.
- Never heat a flammable substance with an open flame.
- When transferring flammable liquids in metal equipment, static-generated sparks should be avoided by bonding and the use of ground straps.
- Ventilation is one of the most effective ways to prevent the formation of flammable mixtures. A laboratory hood should be used whenever appreciable quantities of flammable substances are transferred from one container to another, allowed to stand or be heated in open containers, or

handled in any other way. Be sure that the hood is free of all ignition sources including, in particular, variable transformers (variacs).

- ❑ Generally, only small quantities of flammable liquids should be kept at work benches. Larger quantities should be stored away from ignition sources in flammable storage cabinets. It is advisable to purchase highly flammable solvents (e.g., acetone, hexane, diethyl ether, ethyl acetate, tetrahydrofuran) only in metal or break-resistant (e.g., plastic or plastic-coated), containers.
- ❑ Refrigerators used for storage of chemicals must be explosion-proof or flame proof. Storage trays or secondary containers should be used to minimize the distribution of material in the event a container should leak or break.

### **3.2.9. Take additional precautions for handling highly reactive or peroxide forming substances.**

Highly reactive substances are materials that decompose under conditions of mechanical shock, elevated temperature, or chemical action, with the release of large volumes of gases and heat. Special precautions are required for the safe use of highly reactive materials. It is the responsibility of the researcher to evaluate the reactive hazards involved in their work and to consult with their supervisor to develop detailed standard operating procedures for any work involving highly reactive substances. Work with highly reactive materials will generally require the use of special protective apparel (face shields, gloves, lab coats) and protective devices such as explosion shields and barriers.

Organic peroxides are among the most hazardous substances handled in campus laboratories. As a class, they are low-power explosives, hazardous because of their sensitivity to shock, sparks, and even friction (as in a cap being twisted open). Many peroxides that are routinely handled in laboratories are far more sensitive to shock and heat than high explosives such as Dynamite or trinitrotoluene (TNT), and may detonate rather than burn. All organic peroxides are highly flammable, and most are sensitive to heat, friction, impact, light, as well as strong oxidizing and reducing agents.

Some peroxides in use at MIT are commercial compounds such as m-chloroperoxybenzoic acid, benzoyl peroxide, hydrogen peroxide, and t-butyl hydroperoxide. However, many common solvents and reagents are known to form peroxides on exposure to air, and these chemicals often become contaminated with sufficient peroxides to pose a serious hazard. Classes of compounds that form peroxides by autoxidation include:

- ❑ Aldehydes including acetaldehyde and benzaldehyde,
- ❑ Ethers with primary and/or secondary alkyl groups, including acyclic and cyclic ethers, acetals, and ketals. Examples include diethyl ether, diisopropyl ether (especially dangerous!), dioxane, dimethoxyethane, tetrahydrofuran, ethyl vinyl ether and alcohols protected as tetrahydropyranyl ethers. Isopropyl alcohol also frequently forms peroxides upon storage.
- ❑ Hydrocarbons with allylic, benzylic, or propargylic hydrogens. Examples of this class of peroxide-formers include cyclohexene, cyclooctene, methyl acetylene, isopropylbenzene (cumene), and tetralin (tetrahydronaphthalene).
- ❑ Conjugated dienes, enynes, and diynes, among which divinylacetylene is particularly hazardous.
- ❑ Saturated hydrocarbons with exposed tertiary hydrogens; common peroxide-formers include decalin (decahydronaphthalene) and 2,5-dimethylhexane.

#### **Precautions for work with peroxide forming materials:**

- ❑ Store peroxide forming materials away from heat and light.

- ❑ Protect peroxidizable compounds from physical damage, heat, and light.
- ❑ Date peroxide formers containers with date of receipt and date of opening. Affixing a label stating "Warning, Peroxide Former" can also be helpful to alert others regarding these materials. Assign an expiration date if one has not been provided by the manufacturer. Recommended safe storage – time periods for peroxide forming chemicals are provided in the EHS SOP #0042 peroxide forming chemicals found on the EHS web site <https://ehs.mit.edu/sops/> (certificate login is required).
- ❑ Peroxide forming chemicals without received, open or manufacturer's expiration date will need to be tested by the lab prior to disposal as well as those containers with expiration dates that have been reached and assigned an expiration date. Any chemical waste streams with >25% peroxide forming chemicals by volume must be tested by the lab and peroxide levels indicated on the red hazardous waste label. If there is greater than 20ppm, a stabilization permit is required prior to shipment and final disposal. (see below)
- ❑ Test for peroxidizables before distilling or evaporating peroxidizable solvents for research purposes. Do not distill for research purposes without treating to remove peroxides. It is illegal to evaporate or treat a regulated waste to avoid disposal of that material. All waste material should be disposed of properly as outlined in Part II. Section 8.
- ❑ If crystals are visibly present on the container or lid, or if the container is open but has not been tested, DO NOT OPEN, DO NOT TOUCH. Contact the EHS Office to arrange for disposal.

In the event your lab has any peroxidizable chemicals in inventory please refer to the EHS SOP (#0042) for proper management, storage and testing requirements for use and prior to disposal. If peroxides have formed over 20ppm a stabilization permit is required prior to shipment and final disposal, which the lab will be asked to pay for by EHS. Contact EHS with questions and concerns. The SOP can be found on the EHS web site <https://ehs.mit.edu/sops/> (certificate login is required).

- ❑ Immediately rinse empty containers that once held peroxidizables. Do not let residues evaporate.

For assistance in disposing of larger quantities of peroxides or other explosive materials, contact the EHS Office at 617-452-3477.

### **3.2.10. Take additional precautions for handling explosives.**

Follow manufacturer's instructions for handling and use of explosives. Contact EHS office at 617-452-3477 for assistance

### **3.2.11. Take additional precautions for work with corrosive substances.**

Corrosivity is a complex hazard. Corrosives can be solids, liquids, and gases and includes acids, bases, oxidizers, as well as other chemical classes. Corrosives may belong to more than one chemical class. What is at risk varies, as well. Elemental mercury is considered a toxic substance, but it is shipped as a corrosive substance because it can deteriorate some metals. For purposes of these standard operating procedures, a corrosive is any chemical that can rapidly damage human tissue, metals, and other compounds, such as wood or concrete by chemical action. Store by compatibility. Segregate acids from bases. Segregate oxidizing acids, such as nitric acid from organic acids, such as acetic acid.

- ❑ Store corrosives on a lower shelf or in ventilated corrosive storage cabinets.
- ❑ Make sure containers and equipment, such as tubing, etc. used with corrosive materials is compatible with those materials.
- ❑ Personal protective equipment is important for work with corrosives. Neoprene or rubber gloves, goggles and face shield, rubber apron, and rubber boots should be considered.
- ❑ Always add acid to water, never water to acid.

- ❑ Wherever corrosives are used or stored, be sure there is a working, readily accessible eyewash and safety shower, and
- ❑ Seek medical attention immediately in the event of a potentially injurious exposure.

### **3.3. Additional Procedures for Work with Particularly Hazardous Substances**

#### **3.3.1. Compile Information.**

Before beginning a laboratory operation, each researcher should consult the appropriate literature for information about the toxic properties of the substances that will be used. The precautions and procedures described below should be followed if any of the substances to be used in significant quantities is known to have high acute or moderate chronic toxicity. If any of the substances being used is known to be highly toxic, it is desirable that there be at least two people present in the area at all times. These procedures should also be followed if the toxicological properties of any of the substances being used or prepared are unknown. **Part II 10.3 Appendix II-C p.40** outlines a process for determining whether a chemical is considered a *particularly hazardous substance* (PHS).

#### **3.3.2. Establish designated areas in the laboratory for use of Particularly Hazardous Substances.**

A key requirement of the OSHA Laboratory Standard is that all work with *particularly hazardous substances* be confined to designated areas. The designated area established in your laboratory depends on the circumstances of use for the PHS. A designated area may be the laboratory, a specific area of the laboratory, or a device such as a glove box or fume hood. There also may be designated equipment such as a specific balance, or centrifuge in which you work with or process PHS materials. It is most common for laboratory hoods to serve as designated areas for most research. Laboratory supervisors are required to notify the Chemical Hygiene Officer of the specific location of any designated areas established in their research groups *that are not laboratory hoods*.

#### **3.3.3. Make sure designated areas are posted with a yellow and black caution sign.**

It is the responsibility of laboratory supervisors to define the designated areas in their laboratories and to post these areas with conspicuous signs reading "DESIGNATED AREA FOR USE OF PARTICULARLY HAZARDOUS SUBSTANCES--AUTHORIZED PERSONNEL ONLY". Printed signs can be obtained from the EHS Office. In some cases, it may be appropriate to post additional signs describing unusual hazards present and/or identifying the specific hazardous substances in use. You can also consider marking with yellow tape a section of a bench space or section of a lab hood where PHSs are used.

#### **3.3.4. Use *particularly hazardous substances* only in the established designated areas.**

Using PHSs outside of areas designated for their use, poses a significant danger to you and the others in your laboratory and surrounding areas, as well as violates MIT and OSHA rules and regulations.

#### **3.3.5. Take action to prevent skin contact.**

Contact with the skin is a frequent mode of chemical injury. *Avoid all skin contact with particularly hazardous substances* by using suitable protective apparel including the appropriate type of gloves or gauntlets (long gloves) and a suitable laboratory coat or apron that covers all exposed skin. Always wash your hands and arms with soap and water immediately after working with these materials. In the event of accidental skin contact, the affected areas should be flushed with water and medical attention should be obtained as soon as possible.

#### **3.3.6. Avoid inhalation of PHSs.**

Avoid inhalation of PHSs by ensuring that work involving potential for exposure to a gas, vapor or airborne dust is conducted in a laboratory hood, or other suitable containment device such as a glove box. Purchase material in liquid form rather than powder form when possible.

#### **3.3.7. Thoroughly decontaminate and clean the designated area(s) at regular intervals.**

Decontamination procedures should be established in writing, especially those involving chemical treatments, and consist of any necessary periodic (daily, weekly, etc.) procedures performed to

control exposure of employees. Depending on the chemical material, this may consist only of wiping a counter with a wet paper towel, or periodic use of a neutralizing agent. To determine the proper decontamination procedures, one must consider the chemical (or type of chemical), the amount of chemical used, the specific use, the location of use, and other factors. Contact the EHS Office if assistance is needed to determine the most appropriate decontamination procedures at 617-452-3477.

### **3.3.8. Be prepared for accidents.**

The laboratory worker should always be prepared for possible accidents or spills involving toxic substances. To minimize hazards from accidental breakage of apparatus or spills of toxic substances in the hood, containers of such substances should generally be stored in pans or trays made of polyethylene or other chemically resistant material and, particularly in large-scale work, apparatus should be mounted above trays of the same type of material. Alternatively, the working surface of the hood can be fitted with a removable liner of adsorbent plastic-backed paper. Such procedures will contain spilled toxic substances in a pan, tray, or adsorbent liner and greatly simplify subsequent cleanup and disposal.

If a major release of a particularly hazardous substance occurs outside the hood, then the room or appropriate area should be evacuated and necessary measures taken to prevent exposure of other workers. The EHS Office should be contacted immediately (617-452-3477) for assistance and equipment for spill clean-up. EHS Office personnel can be contacted for assistance after working hours by calling Campus Police (617-253-1212, or 100 from an MIT telephone). Spills should only be cleaned up by personnel wearing suitable personal protective apparel. Contaminated clothing and shoes should be thoroughly decontaminated or incinerated. See Part II. 3.1. for further discussion of the control of accidental releases of toxic substances.

### **3.3.9. Don't contaminate the environment.**

Vapors that are discharged from experiments involving *particularly hazardous substances* should be trapped or condensed to avoid adding substantial quantities of toxic vapor to the hood exhaust air. The general waste disposal procedures outlined in Part II. Section 8. should be followed; however, certain additional precautions should be observed when waste materials are known to contain substances of high toxicity.

### **3.3.10. Recordkeeping.**

It is required that every research group in the department maintain a list of all *particularly hazardous substances* in use in their laboratories, including an inventory of the maximum quantity present at any given time. It is recommended that EHS Representatives be assigned the responsibility for ensuring that this inventory list is kept up to date. In addition, records that include amounts of material used and names of workers involved should be kept as part of the laboratory notebook record of all experiments involving *particularly hazardous substances*.

### **3.3.11. When necessary, restrict access to designated areas when particularly hazardous substances are in use.**

Designated areas should be posted with special warning signs indicating that particularly toxic substances may be in use. As discussed above, many laboratory hoods are designated areas for work with particularly hazardous substances.

## **3.4. Additional Requirements for Work with Select Toxins**

*Select Toxins* are biologically derived toxic chemicals that are specifically regulated by the federal U.S. Department of Health and Human Services under regulation 42 CFR Part 73 when handled at levels above specified quantities. To ensure that MIT inventories of select toxins are maintained at levels below the regulatory threshold, all researchers using these toxins must order them and register their research through the Biosafety Program (BSP) of the EHS Office. For details regarding ordering these materials, contact the BSP at 617-452-3477 or visit the EHS Office website at

<https://ehs.mit.edu/biological-program/select-agent-toxins/>. A list of Select Toxins is provided in Appendix II-C.

These materials are highly toxic and special precautions should be taken whenever handling concentrated forms, even in small amounts. Stocks of these chemicals should be stored under lock and key. A log must be maintained that tracks the use of these materials. Researchers working with these materials should contact the EHS Office for Select Toxin information and should develop a Lab Specific SOP for work with these materials based on *Biosafety in Microbiological and Biomedical Laboratories* (BMBL) guidelines, *Appendix I* (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention and National Institutes of Health, Washington, DC: 1999). This Lab Specific SOP should be maintained and accessible in the researchers' laboratory space and should be provided to the Chemical Hygiene Officer. It is suggested that Select Toxin Lab Specific SOPs be added to the Chemical Hygiene Plan in Part III. Information and a template form are available from the EHS Office for assistance with development of an SOP for work with Select Toxins. Contact the EHS Office at 617-452-3477 for information and assistance.

### 3.5. Special Precautions for Work with Hydrofluoric Acid

Hydrofluoric acid (HF) is a *particularly hazardous substance*, like many acids, but has added dangers that make it especially dangerous to work with. HF is less dissociated than most acids and deeply penetrates the skin. Symptoms of exposure may be delayed for up to 24 hours, even with dilute solutions. HF burns affect deep tissue layers, are extremely painful, and disfiguring. The highly reactive fluoride ion circulates throughout the body and can cause multiple organ toxicity, including heart arrhythmias and death, if not treated. *Any* suspected exposure to HF should be immediately flooded with water, decontaminated with calcium gluconate gel, and treated at MIT Medical.

In case of:

- Large area of skin exposure (greater than the palm of the hand) and the HF concentration is greater than 5%
- Eye exposure
- Inhalation exposure
- Ingestion

Immediately call 100 or 617-253-1212, ask for Advanced Life Support (ALS) Ambulance, follow appropriate irrigation protocol and go directly to the hospital via ALS Ambulance.

All employees are required to be trained by the EHS Office before beginning work with HF. The training covers safe use, personal protective equipment, and decontamination procedures. The training can be taken on the web or in the classroom. Please go to the EHS Training website

<https://ehs.mit.edu/training/>, to register for the training. Please go to the EHS Training website (<https://ehs.mit.edu/training/>) to update training profile, select "Use or work in the area that store or uses hydrofluoric acid" and complete for the training.

All laboratories using HF must have unexpired calcium gluconate decontamination gel on hand. The gel can be obtained at no cost from the EHS Office by submitting request in Hydrofluoric Acid section on this website <https://ehs.mit.edu/chemical-safety-program/chemicals/>.

### 3.6. Special Precautions for Work with Formaldehyde

Formaldehyde is a *particularly hazardous substance* that is widely used at MIT and is covered under a specific OSHA Standard 1910.1048. MIT must identify all laboratory activities that are above the OSHA action level or STEL through initial air monitoring and provide training, medical surveillance, and engineering and work practice controls if air levels warrant it.

Formaldehyde is an animal carcinogen and a suspect human carcinogen according to OSHA and IARC. It is also a sensitizer and can cause allergic skin reactions and asthma-like respiratory symptoms. It is an irritant to eyes, nose, and throat.

The Industrial Hygiene Program (IHP) has performed extensive air sampling for formaldehyde during a variety of lab activities such as animal perfusion, dissections, and tissue fixation and found the results to be below OSHA levels provided that suitable exhaust ventilation is used. Almost all formaldehyde procedures should be performed with ventilation such as a fume hood, slot hood, or vented downdraft table. All work should be done using gloves with adequate resistance to formaldehyde, such as the Best N-Dex brand (a disposable nitrile glove).

With proper exhaust ventilation, you should not detect any odors from formaldehyde work nor experience any symptoms of exposure such as eye tearing or throat irritation. If you do, please contact IHP immediately at 617-452-3477 for an evaluation. IHP sends a questionnaire annually to laboratory EHS representatives to survey formaldehyde use and conducts air sampling of procedures where there may be a potential for exposure. Notify IHP for an evaluation if your procedures change and you work with large quantities of formaldehyde, perform animal perfusions, or do extensive tissue dissection work.

### 3.7 Special Precautions for Work with Nanomaterials

Nanomaterials are defined by the ASTM as a material with two or three dimensions between 1 to 100 nm. They can be composed of many different base materials (carbon, silicon, and metals such as gold, cadmium, and selenium). They can also have different shapes: such as nanotubes, nanowires, crystalline structures such as quantum dots, and fullerenes. Nanomaterials often exhibit very different properties from their respective bulk materials: greater strength, conductivity, and fluorescence, among other properties.

The toxicity of most nanomaterials is currently unknown. Preliminary toxicity testing has indicated that some nanoparticles may be more toxic than the corresponding micron sized particle because of their greater surface area and reactivity. Nano-sized titanium dioxide produces 40 times more lung inflammation than micron-sized particles. In preliminary tests, carbon nanotubes have produced lung inflammation and fibrosis similar to crystalline quartz and asbestos. Nanoparticles are similar in size to viruses and are easily taken up by the body's cells, translocate around the body, and can possibly pass into the brain and through the skin.

The MIT EHS Office considers nanoparticles that have the potential for release into the air to be handled as particularly hazardous substance because their toxicity is, for the most part, unknown and early studies have been suggestive of toxic effects. In the future, many types of nanoparticles may turn out to be of limited toxicity but precaution should be used until more is known. Work with nanoparticles that may release particles should be conducted in enclosures, glove boxes, fume hoods, and other vented enclosures. All work should be done with gloves, t a minimum disposable nitrile gloves. More information on additional precautions and a review of the toxicity of some types of nanomaterials are on the EHS web site at: <https://ehs.mit.edu/chemical-safety-program/chemicals/>

This article also lists good reference sources for researchers to consult to keep up with toxicity information on their materials as it develops. EHS has developed a web course, [Nanomaterials Safety and Health](#) (MIT Atlas Learning Center – requires certificates), which includes information on the toxicity of different types of nanomaterials and laboratory practices to prevent exposures. Currently, nanoparticles and solutions containing them are being disposed of as hazardous waste. Please call the EHS Office at 617-452-3477 for exposure evaluation of experimental setups and additional information.

\*Label all containers of nanomaterials (including waste) with the designation “nano”.

### 3.8 Special Precautions for Work with Cyanide Salts and Compounds

Cyanides have a white crystalline or granular powder appearance and the dry salts are odorless but the reaction with atmospheric moisture may produce hydrogen cyanide which has a faint odor of bitter almonds. They are slightly soluble in water and when mixed with acids will produce lethal hydrogen cyanide gas. Cyanides are used in chemical synthesis and electroplating. A hazard

assessment should be done addressing safe work practices, emergency procedures, roles and responsibilities and training prior to work.

Emergency procedures for cyanide exposure (see also Part IV section 3.4): For a medical emergency and treatment for a confirmed or suspected cyanide exposure we rely on emergency responders by dialing 100 or 617-253-1212 immediately to reach MIT Campus Police. When calling, it is critical to state that it is a potential cyanide exposure and to request a Cambridge Fire Dept. Paramedic Company ambulance service equipped with a CYANOKIT for first aid treatment of cyanide poisoning (See Laboratory Use of Cyanide Salts guidance <https://ehs.mit.edu/chemical-safety-program/chemicals/>).

### 3.9 Special Precautions for Work with Pyrophoric and Water-Reactive Materials

Special precautions are required when working with pyrophoric materials as well as certain water-reactive chemicals

- Pyrophoric materials are solids, liquids and gases that may ignite spontaneously in air.
- Water-reactive substances exposed to water or moisture will release a gas that is either flammable or a health hazard. The information in this section refers to water-reactive substances that have a risk of igniting on contact with moisture.

While these materials may be common reagents in chemistry laboratories, researchers should be aware that these materials have uses in many other types of research including material science and semiconductor research.

Due to the uniquely hazardous properties of these two classes of materials it is required that a hazard assessment be done and laboratory SOP must be completed if the general SOP provided in Part II 3.3 for work with Particularly Hazardous Substances of this Plan DOES NOT adequately ensure the protection of personal health and safety, and the environment for its use. The SOP should include information on storage, usage, disposal, appropriate PPE and emergency procedures for the material in the lab. See part III for a template that may be used for developing lab specific SOPs.

Guidance on pyrophoric and water-reactive materials and a list of materials that are pyrophoric or water reactive can be found at <https://ehs.mit.edu/chemical-safety-program/chemicals/>

Details on specific requirements for labs with pyrophoric materials can be found in the MIT EHS Pyrophorics SOP at [https://ehs.mit.edu/site/system/files/secure/sop\\_004\\_3.pdf](https://ehs.mit.edu/site/system/files/secure/sop_004_3.pdf)

Refer to both resources before handling pyrophoric or water-reactive materials.

### 3.10 Special Precautions for Work with Cytotoxic Drugs

Cytotoxic drugs (sometimes known as antineoplastics) describe a group of chemicals which are toxic to cells, preventing their replication or growth. They are frequently used to treat cancer. It is recommended that any work with cytotoxic powders be carried out in an exhausted biological safety cabinet (either a Class II A2 with a thimble connection or Class II B2). For any work with cytotoxics that are volatile it is recommended that any work be carried out in a Class II B2 biological safety cabinet.



## 4. PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE), to include eye and face protection, gloves, protective clothing, head protection, hearing protection, protective footwear, and respiratory protection may be needed to ensure an employee is adequately protected from hazards associated with the work they are doing. Refer to the table in Section 3.1 for an overview of PPE and clothing requirements in labs.

### 4.1. PPE Hazard Assessment

When personal protective equipment is needed, it is required by regulation that a hazard assessment be made to identify the specific hazards of concern and the PPE required for protection from those hazards. This hazard assessment may be done for a work area, or for a specific experiment, job, or task. The protective equipment is selected based on the hazard assessment. This assessment needs to be documented in writing. This hazard assessment and documentation requirement would be satisfied through the application of the standard operating procedures outlined in this Chemical Hygiene Plan, namely Part II. Section 3. or through the development of additional Lab Specific SOPs in Part III., except for the use of respiratory protective equipment. If you believe respiratory protection is warranted, you must first contact the Environment, Health and Safety (EHS) Office for a consultation. For more information on PPE, visit the EHS Office website at <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/>

### 4.2. Laboratory coats

The MIT Committee on Toxic Chemicals and the Institute EHS Council has established the following policy with respect to laboratory coats. A laboratory coat or equivalent protection is required when working with or when working nearby to hazardous chemicals, unsealed radioactive materials, and biological agents at BL2 or greater. A flame resistant lab coat is required when handling pyrophoric substances outside of a glove box. It is recommended that a flame resistant lab coat be worn when working with all flammable chemicals. Laboratory supervisors shall carry out a hazard assessment to identify situations (a task, experiment, or area) where alternative or more protective apparel must be worn.

EHS website <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/> provides additional details to aid in the process of performing a hazard assessment to select an appropriate lab coat based on the hazards in the lab area, and provides information on the use and care of lab coats, including laundry service options.

### 4.3. Gloves

Gloves for work with chemicals must be selected based on the potential contact hazard, and the permeability of the glove material. For incidental skin contact with small amounts of chemicals on a surface, or work with most powders, disposable nitrile gloves are usually adequate. For work involving materials that are readily absorbed through the skin, the glove must be carefully selected using glove impermeability charts. Silver Shield brand gloves work well for many common laboratory chemicals that can be absorbed through the skin, but you should verify their effectiveness for your application. You should also evaluate need for hand protection from physical hazards such as extreme heat or cold, and make sure you use appropriate gloves.

### 4.4. Eye Protection

The Committee on Toxic Chemicals established a policy in 2009 to assure special emphasis is placed on the use of appropriate eye protection for work with hazardous chemicals in laboratories. The policy states:

“For every laboratory room where hazardous chemicals are stored or are in use a determination must be made as to the level of eye protection that shall be required. The level of eye protection required shall be identified in writing. Where no determination has been made regarding the level of eye protection required in an area, the default shall be that eye protection is required.”

Eye protection is also required when there is the potential for eye injury due to other hazards besides hazardous chemicals. Examples of this include working with tools, power tools, and/or shop equipment when the work emits debris or flying particles, or when working with molten metal. Work with unsealed radioactive sources, lasers and certain biological agents also require eye protection by regulation.

Eye protection provided shall meet the requirements of ANSI/ISEA Z87.1-2015, or equivalent.

**MRL Eye Protection Policy- Safety glasses are required in all laboratory areas where hazardous chemicals are stored or used.** The entrance to each of these laboratories is posted with a sign indicating the requirement. Safety goggles or face shields should be worn when splash potential is high. Guidance for assessing the level of additional eye protection required is available at: <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/>.

**If the PI believes that eye protection is not required in all areas of the lab**, then hazard assessments are performed to identify the eye protection requirements. The EHS Coordinator and EHS lab rep conduct hazard assessments to determine the eye protection required for each lab area and document the assessment on the PPE Hazard Assessment form available at <http://ehs.mit.edu/site/content/general-requirements>. The EHS Office Guidance Document "Eye Protection in Laboratories Assessment, Selection, Use and Maintenance" is used to guide eye protection selection. It is available at: <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/>.

The assessments are reviewed and initialed by the PI. Copies of the eye protection assessments are maintained in a Lab Safety notebook, which is reviewed with new personnel to the lab. When new experiments or procedures are introduced to the lab, an assessment is made, as above, and personnel are informed of any changes. The requirements are reviewed at least annually in the lab specific chemical hygiene training.

All personnel in the lab are provided safety glasses. The procedure for obtaining prescription glasses is described at: <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/>. Other eye protection, such as goggles or face-shields, is to be made available where needed.

Visitor glasses are provided in individual lab spaces for visitors to the lab when there is a likelihood they will be exposed to eye hazards.

**If you are concerned that your labmates are not wearing the required eye protection, discuss it with your EHS Rep and PI. The PI is responsible for enforcing eye protection requirements.**

- **Ordinary prescription glasses do not provide adequate protection against injury.** Their use should be limited to providing minimal protection when you are present in the laboratory, but not for carrying out a chemical operation.
- **Contact lenses** offer no protection against eye injury and cannot be substituted for safety glasses or goggles. It is best not to wear contact lenses when carrying out operations where a chemical splash to the eyes is possible, since contact lenses can interfere with first aid and eye-flushing procedures.
- **Goggles** should be worn when carrying out operations in which there is reasonable danger from splashing chemicals, flying particles, etc. For example, goggles are preferred over regular safety glasses when working with glassware under reduced or elevated pressures (e.g., sealed tube reactions), when handling potentially explosive compounds (particularly during distillations), and when employing glass apparatus in high-temperature operations. In some instances, "safety shields" should be set up around experiments for additional protection. Since goggles offer little protection to the face and neck, **full-face shields** should be worn when conducting particularly hazardous laboratory operations. In addition, the use of laser or ultraviolet light sources requires special glasses or goggles that have been approved by the EHS Office to be worn.

- When **changes** are made in a lab that may introduce eye hazards to a location where they are not currently present, an assessment must be performed to determine if it will be an eye hazard area where eye protection is required. The process described above is used for that assessment, and if required, the area must be labeled with appropriate signage. All lab personnel must be informed of any changes made.

## 5. OTHER SAFETY AND STORAGE EQUIPMENT

### 5.1. Laboratory Fume Hoods/Ventilation

#### Laboratory Fume Hoods

Local exhaust ventilation is the primary method used to control inhalation exposures to hazardous substances. The laboratory hood is the most common local exhaust method used on campus; other methods include vented enclosures for large pieces of equipment or chemical storage, and snorkel types of exhaust for capturing contaminants near the point of release. Some systems are equipped with air cleaning devices (HEPA filters or carbon adsorbers).

*It is advisable to use a laboratory hood when working with all hazardous substances.* In addition, a laboratory hood or other suitable containment device must be used for all work with "particularly hazardous substances". For more information see Part II. Section 3.3. A properly operating and correctly used laboratory hood can control the vapors released from volatile liquids as well as dust and mists.

#### General Rules

The following general rules should be followed when using laboratory hoods:

- A. No hoods should be used for work involving hazardous substances unless it has a certification label less than one year old.
- B. Always keep hazardous chemicals at least six inches behind the plane of the sash.
- C. Never put your head inside an operating laboratory hood to check an experiment. The plane of the sash is the barrier between contaminated and uncontaminated air.
- D. Work with the hood sash in the **lowest possible position**. The sash will then act as a physical barrier in the event of an accident in the hood. Keep the sash closed when not conducting work in the hood.
- E. Do not clutter your hood with bottles or equipment. Keep it clean and clear. Only materials actively in use should be in the hood. This will provide optimal containment and reduce the risk of extraneous chemicals being involved in any fire or explosion that may occur in the hood.
- F. Clean the grill along the bottom slot of the hood regularly so it does not become clogged with papers and dirt.
- G. Promptly report any suspected hood malfunctions to the Industrial Hygiene Program (617-452-3477).

Do not make any modifications to hoods or duct work without first contacting the DLC EHS Coordinator and the Industrial Hygiene Program (617-452-3477). Any changes made to the local exhaust system must be approved by the Industrial Hygiene Program. Do not use a laboratory hood for large pieces of equipment unless the hood is dedicated to this use (large obstructions can change the airflow patterns and render the hood unsafe for other uses). It is generally more effective to install a specifically designed enclosure for large equipment so that the laboratory hood can be used for its intended purpose.

The Industrial Hygiene Program annually inspects all laboratory hoods on campus. This inspection consists of measuring the face velocity of the hood and using a smoke stick to check its containment

effectiveness visually. If the laboratory hood passes both the face velocity and smoke containment tests, then it is posted with an updated certification label. If the hood does not pass and the problem is so severe that the hood is unsafe for use, then it is labeled with a "DO NOT USE" sign. For more information on fume hoods, please visit <https://ehs.mit.edu/lab-research-program/fume-hoods-laboratory-ventilation/>

## 5.2. Fires, Fire Extinguishers, Safety Showers, and Eyewash Stations

### 5.2.1. Fire Extinguishers

Laboratory supervisors are required to instruct new personnel in the location of fire extinguishers, safety showers, and eyewashes *before* they begin research in the laboratory. Laboratories where a potential fire hazard exists (use and/or storage of flammable and combustible liquids, solids, or gases; any spark producing work, welding, use of open flames, etc.) should be outfitted with fire extinguishers. All fire extinguishers should be mounted on a wall in an area free of clutter or stored in a fire extinguisher cabinet. Research personnel should be familiar with the location, use, and classification of the extinguishers in their laboratory.

It is MIT policy that personnel are not required to extinguish fires that occur in their work areas and are not permitted to use fire extinguishers unless properly trained. To be trained, researchers may attend the Fire Extinguisher Familiarization Course offered by EHS. Always activate the nearest fire alarm pull station before attempting to use a portable fire extinguisher. Refer to MIT's standard operating procedure on Portable Fire Extinguishers available at <https://ehs.mit.edu/sops> (certificate login is required), for additional information. Any time a fire extinguisher is used, it should be reported to the MIT Operations Center (x3-1500) or EHS (2-3477).

#### Controlling Fires

In the event of a fire, activate the nearest fire alarm to order evacuation of the building and summon assistance from the Fire Department. When the fire alarm sounds, all personnel are required to leave the building. Call 100 when in a safe place to report the fire. MIT Policy states that personnel are not required to fight fires. The following guidelines should be followed to prevent and minimize injury and damage from fires.

- **Be prepared!** Know where all of the fire extinguishers are located in your laboratory, what types of fires they can be used for, and how to correctly operate them. Know where the nearest fire alarm is located. Know the location of safety showers and fire blankets.
- **Fires in small vessels** can usually be suffocated by loosely covering the vessel. Never pick up a flask or container of burning material.
- **In the event of a more serious fire**, evacuate the laboratory and activate the nearest fire alarm. Be prepared to meet and advise the Fire Department and Emergency Response Team with regard to what hazardous substances are present in your laboratory.
- **A small fire that just started** can sometimes be extinguished with a laboratory fire extinguisher. **Extinguishing such fires should only be attempted if you are confident that you can do so successfully and quickly, and from a position where you are always between the fire and an exit from the laboratory.** Do not underestimate fires and remember that toxic gases and smoke may present additional hazards.
- **Small fires involving reactive metals and organometallic compounds** (such as magnesium, sodium, potassium, metal hydrides, etc.) should be extinguished with Met-L-X or Met-L-Kyl (see Part II-B.5), or by covering with dry sand.
- **Personal injuries involving fires:** Immediately dropping to the floor and rolling can sometimes extinguish minor clothing fires. If a person's clothing catches fire, he or she should be doused with water from the safety shower. Fire blankets should only be used as a last-resort measure to extinguish fires since they tend to hold in heat and to increase the severity of burns. Quickly remove contaminated clothing, douse the person with water, and place clean, wet, cold cloth on burned areas. Wrap the injured person in a blanket to avoid shock and get medical attention promptly.

#### Specific Hazards That May Lead to Fires or Explosions

The combination of certain compounds or classes of compounds can result in a violent chemical reaction leading to an explosion or fire. Other compounds pose explosion or fire hazards when exposed to heat, shock, or other conditions. Listed below are some of the specific compounds and combinations of compounds that may pose explosion or fire hazards and may be encountered in MRL laboratories. This list is not intended to be complete, and researchers should always be familiar with the flammability and other properties of the chemicals involved in their research.

- **Acetylenic compounds** are explosive in mixtures of 2.5-80% with air. At pressures of 2 or more atmospheres, acetylene subjected to an electrical discharge or high temperature decomposes with explosive violence. Dry acetylides can detonate on receiving the slightest shock. Many heavy metal acetylides are sensitive explosives.
- **Aluminum chloride** should be considered a potentially dangerous material. If moisture is present, there may be sufficient decomposition (generating HCl) to build up considerable pressure. If a bottle is to be opened after long standing, it should be completely enclosed in a heavy towel.
- **Ammonia** reacts with iodine to give nitrogen triiodide, which is explosive, and with hypochlorites to give chlorine. Mixtures of ammonia and organic halides sometimes react violently when heated under pressure.
- **Azides** such as sodium azide can displace halide from chlorinated hydrocarbons such as dichloromethane to form highly explosive organic polyazides; this substitution reaction is facilitated by the presence of solvents such as DMSO.
- **Dry benzoyl peroxide** is easily ignited and sensitive to shock and may decompose spontaneously at temperatures above 50 °C. It is reported to be desensitized by addition of 20% water.
- **Carbon disulfide** is both very toxic and very flammable. Mixed with air, its vapors can be ignited by a steam bath or pipe, a hot plate, or by a glowing light bulb.
- **Chlorine** may react violently with hydrogen or with hydrocarbons when exposed to sunlight.
- **Diazomethane** and related compounds should be treated with extreme caution. They are very toxic (potent carcinogens), and the pure gases and liquids readily explode. Solutions in ether are safer with regard to shock sensitivity.
- **Dimethyl sulfoxide** decomposes violently on contact with a wide variety of active halogen compounds. Explosions from contact with active metal hydrides have been reported.
  1. **Diethyl, diisopropyl, and other ethers** (particularly the branched-chain type) sometimes explode during heating or refluxing because of the presence of peroxides. Ferrous salts or sodium bisulfite can be used to decompose these peroxides, and passage over basic active alumina will remove most of the peroxidic material. In general, however, old samples of ethers should be carefully and properly disposed of.
- **Ethylene oxide** has been known to explode when heated in a closed vessel. Experiments using ethylene oxide under pressure should be carried out behind suitable barricades.
- **Halogenated compounds** such as chloroform, carbon tetrachloride, and other halogenated solvents should not be dried with sodium, potassium, or other active metals; violent explosions usually occur upon treatment of these solvents with active metals.
- **Hydrogen peroxide** stronger than 3% can be dangerous: in contact with the skin, it may cause severe burns. Thirty percent hydrogen peroxide can decompose violently if contaminated with iron, copper, chromium, or other metals or their salts.

- **Liquid-nitrogen** cooled traps open to the atmosphere rapidly condense liquid air. When the coolant is later removed, an explosive pressure buildup may then occur—usually with enough force to shatter glass equipment. Hence, only sealed or evacuated equipment should be cooled with liquid nitrogen.
- **Lithium aluminum hydride** should not be used to dry ethyl ether or tetrahydrofuran; fires from this are very common. The products of the reaction of LAH with carbon dioxide have been reported to be explosive. Carbon dioxide or bicarbonate extinguishers should not be used against lithium aluminum hydride fires, which should be smothered with sand or some other inert substance.
- **Oxygen tanks:** Serious explosions have resulted from contact between oil and high-pressure oxygen. Oil should not be used on connections to an oxygen cylinder.
- **Ozone** is a highly reactive and toxic gas. It is formed by the action of ultraviolet light on oxygen (air) and, therefore, certain ultraviolet sources may require venting to the exhaust hood. Liquid and solid ozone are explosive substances.
- **Palladium or platinum on carbon, platinum oxide, Raney nickel, and other catalysts** should be filtered from catalytic hydrogenation reaction mixtures carefully. The recovered catalyst is usually saturated with hydrogen and highly reactive and thus will enflame spontaneously on exposure to air. When filtering hydrogenation reaction mixtures (particularly large-scale reactions), the filter cake should not be allowed to become dry. The funnel containing the still-moist catalyst filter cake should be put into a water bath immediately after completion of the filtration. Note that another hazard in working with such catalysts is the danger of explosion if additional catalyst is added to a flask in which hydrogen is present.
- **Parr bombs** used for hydrogenations are known to explode. They should be handled with care behind shields and the operator should wear goggles.
- **Perchlorates:** The use of perchlorates should be avoided whenever possible. Perchlorates should not be used as drying agents if there is a possibility of contact with organic compounds, or if they will be in proximity to a dehydrating acid strong enough to concentrate the perchloric acid to more than 70% strength (e.g., in a drying train that has a bubble counter containing sulfuric acid). Safer drying agents should be used. Seventy percent perchloric acid can be boiled safely at approximately 200 °C, but contact of the boiling undiluted acid or the hot vapor with organic matter, or even easily oxidized inorganic matter (such as compounds of trivalent antimony), will cause serious explosions. Oxidizable substances must never be allowed to contact perchloric acid. Beaker tongs, rather than rubber gloves, should be used when handling fuming perchloric acid. Perchloric acid evaporations should be carried out in a hood that has a good draft and a built-in water spray for the ductwork behind the baffle. Frequent (weekly) washing out of the hood and ventilator ducts with water is necessary to avoid danger of spontaneous combustion or explosion if this acid is in common use.
- **Permanganates** are explosive when treated with sulfuric acid. When both compounds are used in an absorption train, an empty trap should be placed between them.
- **Peroxides (inorganic):** When mixed with combustible materials, barium, sodium, and potassium peroxides form explosives that ignite easily.
- **Phosphorus** (red and white) forms explosive mixtures with oxidizing agents. White P should be stored under water because it is spontaneously flammable in air. The reaction of P with aqueous hydroxides produces highly toxic phosphine, which may ignite spontaneously in air or explode.
- **Phosphorus Trichloride** reacts with water to form phosphorous acid, which decomposes on heating to form phosphine, which may ignite spontaneously or explode. Care should be taken in opening containers of phosphorous trichloride, and samples that have been exposed to moisture should not be heated without adequate shielding to protect the operator.

- **Potassium** is in general more reactive than sodium. It ignites quickly on exposure to humid air and, therefore, should be handled under the surface of a hydrocarbon solvent such as mineral oil or toluene. Oxidized coatings should be carefully scraped away before cutting potassium metal as explosions can otherwise occur.
- **Residues from vacuum distillations** have been known to explode when the still apparatus was vented to the air before the distillation pot residue was cool. Such explosions can be avoided by venting the still pot with nitrogen, cooling it before venting, and restoring the pressure slowly.
- **Sodium** (Na) should be stored in a closed container under kerosene, toluene, or mineral oil. Scraps of Na or K should be destroyed by reaction with *n*-butyl alcohol. Contact with water should be avoided because Na reacts violently with water to form hydrogen with evolution of sufficient heat to cause ignition. Carbon dioxide, bicarbonate, and carbon tetrachloride fire extinguishers should **not** be used on alkali metal fires.

When transporting, storing, using, or disposing of any substance, utmost care must be exercised to ensure that the substance cannot accidentally come in contact with another material with which it is incompatible. Such contact can result in a serious explosion or the formation of substances that are highly toxic, flammable, or both. The following table is a guide to avoiding accidents involving **incompatible substances**.

### Examples of Incompatible Chemicals

Chemical	Is Incompatible With
Acetic acid	Chromic acid, nitric acid, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Acetone	Concentrated nitric acid and sulfuric acid mixtures
Alkali and alkaline earth metals (such as powdered aluminum or magnesium, calcium, lithium, sodium, potassium)	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, halogens
Ammonia (anhydrous)	Mercury (in manometers, for example), chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
Ammonium nitrate	Acids, powdered metals, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent
Azides	Acids
Bromine	See Chlorine
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, alcohol, flammable liquids in general
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals, turpentine
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids (organic or inorganic)
Cyanides	Acids
Decaborane	Carbon tetrachloride and some other halogenated hydrocarbons

Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Fluorine	Everything
Hydrocarbons (such as butane, propane, benzene)	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkali
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, combustible materials
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitrates	Sulfuric acid
Nitric acid (concentrated)	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, brass, any heavy metals
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury
Oxygen	Oils, grease, hydrogen, flammable liquids, solids, or gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorous (white)	Air, oxygen, alkalis, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids
Potassium perchlorate (see also chlorates)	Sulfuric and other acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerine, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate, (similar compounds of light metals such as sodium, lithium)
Tellurides	Reducing agents

#### 4.1 Effectiveness of Various Fire Extinguishers on Different Classes of Fires

	<b>Class A</b> (Paper & Trash)	<b>Class B</b> (Burning Liquids, Solvents)	<b>Class C</b> (Electrical)	<b>Class D</b> (Metal)	<b>Notes</b>
Carbon Dioxide Extinguisher	Not Very Effective	Effective	Effective	Not Effective	Do not use in fires containing: alkali, Al, Mg, lithium aluminum hydride.
Dry Powder Extinguisher	Effective	Effective	Effective	Not Effective	Not recommended for fires involving delicate or optical instruments.



Water Extinguisher	Effective	Not Effective	Not Effective	Not Effective	
Met-L-X, Met-L-Kyl	Not Effective	Not Effective	Not Effective	Effective	
Sand	Effective	Effective	Effective	Effective	Especially effective for <i>small</i> Class D (metal) fires.

### Handling Leaking Gas Cylinders

Occasionally, a gas cylinder or one of its components parts develops a leak. Most such leaks occur at the top of the cylinder in areas such as the valve threads, safety device, valve stem, and valve outlet. If a leak is suspected, do not use a flame for detection; rather, a flammable-gas leak detector or soapy water or other suitable solution should be used. If the leak cannot be remedied by tightening a valve gland or a packing nut, emergency action procedures should be effected and the supplier should be notified. Laboratory workers should never attempt to repair a leak at the valve threads or safety device; rather, they should consult with the supplier for instructions.

The following general procedures can be used for relatively minor leaks where the indicated action can be taken without the exposure of personnel to highly toxic substances. Note that if it is necessary to move a leaking cylinder through populated portions of a building, place a plastic bag, rubber shroud, or similar device over the top and tape it (duct tape preferred) to the cylinder to confine leaking gas.

- i. **Flammable, inert, or oxidizing gases** – Move the cylinder to an isolated area (away from combustible material if the gas is flammable or an oxidizing agent) and post signs that describe the hazards and state warnings. If feasible, leaking cylinders should always be moved into laboratory hoods.
- ii. **Corrosive gases** may increase the size of the leak as they are released and some corrosives are also oxidants or flammable. Move the cylinder to an isolated, well-ventilated area and use suitable means to direct gas into an appropriate chemical neutralizer. Post signs that describe the hazards and state warnings.
- iii. **Toxic gases** – Follow the same procedure as for corrosive gases. Move the cylinder to an isolated, well-ventilated area and use suitable means to direct the gas into an appropriate chemical neutralizer. Post signs that describe the hazards and state warnings.

When the nature of the leaking gas or the size of the leak constitutes a more serious hazard, self-contained breathing apparatus and protective apparel may be required. Evacuate personnel from the affected area (activate the fire alarm to order the evacuation of the building) and call Campus Police (dial 100) to obtain emergency assistance.

### 5.2.2. Safety Showers and Eyewash Stations

Every laboratory where the use of materials that are either corrosive or that otherwise present a significant skin/eye contact or absorption hazard must have access to an unobstructed safety shower and eyewash facility that meets the requirements of OSHA regulations (29 CFR 1910.151(c)). For the weekly inspection of the eyewash it is recommended that in each lab a person, such as the EHS Representative or EHS Coordinator, be assigned the inspection task that includes checking access and flushing the eyewash by running the water for one minute. This will flush out any bacteria that grow in the stagnant water. If an eyewash or safety shower needs to be repaired create and submit a service request to the Dept. of Facilities in Atlas <https://atlas.mit.edu/>. All showers are tested twice a year by Facilities if one or more shower inspections are out of date use the above link submit a service request include the bldg.-room number(s).

### 5.3. Safe Use of Warm and Cold Environmental Rooms

Both warm and cold rooms at MIT use a refrigerant gas (Freon-22, R-12, or MP39) to control temperatures. In order to keep temperatures stable, there is minimal ventilation to the rooms. These

rooms are NOT designed for chemical use because of the minimal ventilation. Do not store flammable, volatile toxic or corrosive chemicals in cold or environmental rooms unless they have been specifically designed for such purposes. Storage or use of dry ice should not be done in cold rooms because large quantities of carbon dioxide are released when dry ice sublimates, displacing oxygen in the room.

Each room is alarmed if the temperature changes by more than one degree, which may indicate that a door has been left open or in rare instances, that refrigerant gas is leaking. If an alarm sounds, please leave the room and the alarm should reset. If it does not, please call the Department of Facilities (617-253-4948, or FIXIT from an MIT telephone) and report the alarm condition. Do not enter the room until it has been checked. Minimize time spent in environmental rooms. Notify a coworker if you are using the room alone.

If you have any questions about work or general air quality in environmental rooms, please contact the Industrial Hygiene Program (617-452-3477) for an evaluation. For more information on safe use of warm and cold rooms, go to <https://ehs.mit.edu/lab-research-program/warm-and-cold-rooms/>.

#### 5.4. Electrical Safety and Lockout/tagout Considerations

Electricity can be an invisible hazard if not handled appropriately. The hazard level increases as failures to follow electrical safety practices increase. Below are some considerations that will help protect yourself and others when working with electricity.

- ❑ Monitor equipment loads so that electrical circuits do not trip.
  - Do not daisy chain extension cords and power strips
  - High amperage or heat producing equipment (ovens, refrigerators, hot plates, heaters, etc.) **should** be plugged directly into a wall outlet and not into a power strip or extension cord.
  
- ❑ Purchase equipment that is listed or labelled by a Nationally Recognized Testing Lab (NRTL). Visit [this site](#) for a list of all the current NRTLs.
  
- ❑ Contact EHS **if you need** assistance reviewing any modified or researcher build lab equipment. More complicated equipment may require an external consultant to assist with this review.
  
- ❑ When working on equipment maintenance or removing guards, control of any hazardous energies is essential for personnel safety. Follow [OSHA 1910.147](#) requirements for locking and tagging of these energy sources. There are three main components to a successful program;
  - Training for authorized and affected personnel
  - Written Energy Control Procedures (ECPs)
  - Periodic Program Inspection
  - **For more information go the EHS LOTO Webpage <https://ehs.mit.edu/workplace-safety-program/lotol/>**
  
- ❑ When all energy sources cannot be isolated from equipment by unplugging during maintenance or other activities, lab personnel **shall** contact DOF to have the electrical or other source of energy/pressure be mitigated and locked out by DOF.

The hazard analysis for new research should include electrical safety when appropriate. Contact EHS to review any procedure or equipment setup that exposes lab personnel to unguarded hazardous voltages of >50 Volts.

## 6. CHEMICAL CONTAINER LABELING GUIDELINES

Labeling is important for safe management of chemicals, preventing accidental misuse, inadvertent mixing of incompatible chemicals, and facilitating proper chemical storage. Proper labeling helps assure quick

response in the event of an accident, such as a chemical spill or chemical exposure incident. Finally, proper labeling prevents the high costs associated with disposal of “unknown” chemicals.

**Labeling requirements.** With the exception for transient containers that will contain chemicals for brief periods, one day or less, all containers of chemicals being used or generated in MIT research laboratories must be labeled sufficiently to indicate contents of the container. On original containers, the label should not be removed or defaced in any way until the container is emptied of its original contents. Incoming containers should be inspected to make sure the label is in good condition. It is also advisable to put a date on new chemicals when they are received in the lab, and to put a date on containers of chemicals generated in the lab and the initials of the responsible person. For chemical management expiration dates should also be placed on the label see Part II section 3.2.9 Precautions for Work with Peroxide Forming Chemicals page 25 of this document.

Abbreviations, or other acronyms may be used to label containers of chemicals generated in the lab, as long as all personnel working in the lab understand the meaning of the label or know the location of information, such as a lab notebook, or log sheet that contains the code associated with content information. In addition, small containers, such as vials and test tubes, can be labeled as a group by labeling the outer container (e.g., rack or box). Alternatively, a placard can be used to label the storage location for small containers (e.g., shelf, refrigerator, etc.).

Containers of practically non-toxic and relatively harmless chemicals must also be labeled with content information, including containers such as squirt bottles containing water.

## 7. COMPRESSED GAS CYLINDERS

Compressed gas cylinders are used in many workplaces to store gases that vary from flammable (acetylene) to inert (helium). Many of these cylinders store gases at high pressures that can turn a damaged cylinder into a torpedo, capable of going through multiple concrete block walls. Other cylinders store the contents as a liquid (acetylene) and have special orientation requirements. If handled properly, compressed gas cylinders are safe. Regardless of the properties of the gas, any gas under pressure that is improperly stored can result in a hazardous release of energy.

Any person who handles compressed gas cylinders should be informed of their potential health and safety hazards and trained to handle them properly. The EHS Office has developed a standard operating procedure, “Compressed Gases”, located at <https://ehs.mit.edu/chemical-safety-program/compressed-gas-cylinder-safety/> for ordering or removal of gas cylinders.

For additional advice, and/or assistance in training, contact the EHS Office.

## 8. CHEMICAL WASTE MANAGEMENT

### 8.1. Waste Management Responsibility

Hazardous waste may be generated from laboratory operations, construction and renovation activities, photo processing, and a variety of other activities at the Institute. The proper disposal of waste chemicals at the Institute is of serious concern, and every effort must be made to do it safely and efficiently. The responsibility for the identification and proper management of waste chemicals within the Institute prior to pick-up by the Environment, Health and Safety Office or their designated contractor, rests with the individuals who have generated the waste.

### 8.2. Training

All personnel using hazardous chemicals must complete the training requirements on managing hazardous waste as outlined in Part I. Section 3. of this Plan.

### 8.3. Procedures for Hazardous Waste Generators

The following summary provides a general overview of regulatory requirements applicable to hazardous waste generators.

#### 8.3.1. Waste Identification

##### A. Waste Identification:

Hazardous waste (HW) includes materials that possess hazardous characteristics (e.g. toxic, ignitable, corrosive or reactive), or substances that are listed as hazardous waste by the regulatory agencies.

##### B. Containers and Labeling:

Separate containers must be used for different categories of chemical wastes and the container must be compatible with the waste contained. Compatible wastes can be consolidated. Empty containers in the lab can be reused for collecting hazardous waste provided the old label is removed or completely defaced. Only compatible chemicals shall be combined in a container. Any chemicals spilled on the outside of the container must be immediately cleaned off. Containers that store hazardous waste must be properly and clearly labeled. Labels must include: 1) the words "Hazardous Waste"; 2) the chemical names of constituents written-out with no abbreviations (e.g. "ethanol"); and 3) the hazards associated with the waste in words (e.g. "TOXIC"). **The hazardous waste labels are available from the EHS Office Environmental Management Program (617-452-3477 or <https://ehs.mit.edu/regulated-waste-program/chemical-waste/>).**

#### 8.3.2. Accumulation and Storage

##### A. Accumulation & Storage:

Federal Environmental Protection Agency (U.S. EPA) and Massachusetts state regulations allow for two types of hazardous waste management areas: less than 90-day storage areas (90-day areas) and satellite accumulation areas (SAAs).

*Satellite Accumulation Areas:* SAAs must be established at or near the point of generation and remain under the control of the person generating the waste. SAAs must be clearly delineated and are to be posted with the sign "Hazardous Waste Satellite Accumulation Only." The Environmental Management Program has green "Hazardous Waste Satellite Accumulation Only" stickers available upon request.

A maximum of 55 gallons of hazardous waste or 1 quart of acutely hazardous waste may be accumulated at each SAA. Only one in-use container is allowed per waste stream. Hazardous waste containers must be closed unless waste is being added to the container.

Hazardous wastes with free liquids must be kept within secondary containment. EMP will provide secondary containers upon request. In addition, containers of incompatible wastes must be kept segregated and stored in separate secondary containers.

Hazardous waste containers in SAAs must be marked or labeled with the following:

- The words "Hazardous Waste"
- The hazardous waste(s) identified in words (e.g., acetone, toluene)
- The type of hazard(s) associated with the waste(s) indicated in words (e.g., ignitable, toxic, etc.)

Once a hazardous waste container is filled, the label must be dated and the container removed from the satellite accumulation area within three business days. The Environmental Management Program provides a hazardous waste pick-up service for the waste ready for disposal, or you can move those containers to a 90-day area if one is available. **Hazardous waste pick-up can be requested online at <https://ehs.mit.edu/regulated-waste-program/chemical-waste/> or by calling the Environmental Management Program (617-452-3477).**

*Less than 90 Day Storage Area:* The Environmental Management Program must set up and manage your less than 90-day storage area. EMP will delineate the 90-day area with appropriate markings. All wastes in the 90-day area must be labeled as per SAA requirements with the additional requirement that the date must be marked on the waste tag. Hazardous waste containers must be closed unless waste is being added to the container.

## **B. Inspections**

Hazardous waste areas (satellite accumulation areas and 90-day storage areas) must be inspected on a weekly basis. Personnel managing satellite accumulation areas are responsible for conducting their area's inspections. Environmental Management Program personnel conduct the weekly inspection of all 90-day areas.

### **8.3.3. Waste Minimization**

#### **Guidelines for Waste Reduction**

Plan a procedure for waste disposal before you start on a project. Protection of the environment makes the disposal of large quantities of chemical and solid wastes a difficult problem. It is in everyone's best interest to keep quantities of waste to a minimum.

The following suggestions may help:

- A. Order only the amount of material you need for your project or experiment even if you can get more quantity for the same money.
- B. Use only the amount of material that is needed for conclusive results.
- C. Avoid storing excess material, particularly if it is an extremely toxic or flammable material as this often only adds to the waste stream.
- D. Before disposing of unwanted, unopened, uncontaminated chemicals check with others in your department who may be able to use them.
- E. On termination of a research project or completion of a thesis, all unused chemicals to be kept by the laboratory shall be labeled.
- F. Make sure all samples and products to be disposed of are properly identified, labeled with its chemical name, and containerized. Do not leave them for others to clean up after you.

### **8.3.4. SPECIAL PROCEDURES REQUIRED for Lab Waste Stream**

Unknown waste chemicals cannot be accepted for disposal. It is the responsibility of the Department, Laboratory, or Center involved to identify all chemicals and this may require polling laboratory personnel, students and faculty members to ascertain the owner of such unknown waste and its identity. If identification is not possible, the Environmental Management Program can arrange for analysis of unknown materials and the Principal Investigator/Lab Group will be responsible for the cost of analysis.

Gas cylinders are to be returned to the supplier. Some small lecture bottles are non-returnable, which become a disposal problem when empty or near empty with a residual amount of gas. The Environmental Management Program will arrange for disposal of lecture bottles. However, the Principal Investigator/Lab Group is responsible for the cost of disposal. As outlined in Part IV. Section 2.4, small non-returnable gas cylinders originally purchased from MIT's preferred vendor Airgas, can be returned to the vendor.

Controlled drugs to be discarded *cannot be disposed of as hazardous waste.* The handling, records, and disposal of controlled drugs are the responsibility of the Department, Laboratory, or Center involved operating within the Drug Enforcement Agency (DEA) regulations. However,

the Environmental Management Program can provide assistance during the process.

Laboratories often generate wastes that may consist of a combination of radioactive, biohazardous, or hazardous chemical contaminants. In addition, any waste material contaminated with radioactive, biohazardous or hazardous chemical waste and is also considered a "sharp" requires segregation from other regulated wastes. Consult the EHS Lab Waste Streams Chart for guidance on the proper segregation and labeling of the wastes. The chart may be downloaded from: <https://ehs.mit.edu/sops/> (certificate login is required).

#### 8.4 SPECIAL PROCEDURES FOR LITHIUM AND SODIUM WASTE

- Lithium Metal and Powders – within the glove box / controlled environment, containerize your waste materials and place them under oil. Remove the container of lithium metal, or powder, under oil from the glove box, red tag it and place it in the lab's SAA. Spell out the constituents and indicate Ignitable / Reactive as the associated hazards. Place a waste collection pickup request online for removal from the lab.
- Sodium Metal and Powders - within the glove box / controlled environment, containerize your waste materials and place them under oil. Remove the container of sodium metal, or powder, under oil from the glove box, red tag it and place it in the lab's SAA. Spell out the constituents and indicate Ignitable / Reactive as the associated hazards. Place a waste collection pickup request online for removal from the lab.

#### 8.5 Sink Discharges/Wastewater

The EHS Office has developed a list of chemicals and materials that may be discharged into the sinks or floor drains. The list is based on regulatory requirements, MIT EHS policy, specific buildings, operations and activities knowledge, best practices and professional judgment regarding the potential impact of a chemical if discharged down the drain. The following materials are the only allowable discharges to laboratory sinks:

- Inorganic solutions with pH between 5.5 and 12
- Soaps/detergents
- Mercury-free Bleach/Wescodyne™/Cidex OPA™ / Quatricide® /Cetylcode II solutions
- Aqueous, soluble and dispersible radioactive isotopes into designated sinks or pipe openings within established limits (detailed lists posted at the designated sinks)
- Infectious/Biological materials that have been properly treated as described in each laboratory's registration protocols
- Non-contaminated growth media
- Purified biological materials such as amino acids and proteins in aqueous or buffer solutions
- Sugars and sugar alcohols (polyols) such as glycerol, xylitol and sorbitol
- Buffer solutions
- Spent photo developer (not fixer)
- Inorganic salts for which both the cations and anions are listed in the following table:

<b>Cations</b>	<b>Anions</b>
Aluminum, Al <sup>3+</sup>	Borate, BO <sub>3</sub> <sup>3-</sup> , B <sub>4</sub> O <sub>7</sub> <sup>2-</sup>
Ammonium, NH <sub>4</sub> <sup>+</sup>	Bromide, Br
Calcium, Ca <sup>2+</sup>	Carbonate, CO <sub>3</sub> <sup>2-</sup>
Cesium, Cs <sup>+</sup>	Chloride, Cl
Iron, Fe <sup>+</sup>	Bicarbonate, HCO <sub>3</sub> <sup>-</sup>
Lithium, Li <sup>+</sup>	Bisulfite, HSO <sub>3</sub> <sup>-</sup> , Bisulfate, HSO <sub>4</sub> <sup>-</sup>
Magnesium, Mg <sup>2+</sup>	Fluoride, F <sup>-</sup>

Manganese, $Mn^{2+}$ , $Mn^{3+}$ , $Mn^{4+}$ , $Mn^{7+}$	Hydroxide, $OH^-$
Potassium, $K^+$	Iodide, $I^-$
Sodium, $Na^+$	Nitrate, $NO_3^-$ , Nitrite, $NO_2^-$
Strontium, $Sr^{2+}$	Oxide, $O^{2-}$
Tin, $Sn^{2+}$	Phosphate, $PO_4^{3-}$
Titanium, $Ti^{3+}$ , $Ti^{4+}$	Sulfate, $SO_4^{2-}$ , Sulfide, $SO_3^{2-}$
Zirconium, $Zr^{2+}$	Thiosulfate, $S_2O_3^{2-}$

The list is available as a sticker that **could** be placed near the sink.

All materials that are not on the list of the allowed discharges must be accumulated and managed as hazardous waste. For a case-specific evaluation of materials that are not on the list, a request can be made to the Environmental Management Program (EMP) of the EHS Office or the DLC EHS Coordinator.

## 9. SHIPPING HAZARDOUS AND DANGEROUS MATERIALS

The transportation of hazardous materials and compressed gases over public roads or by air is strictly governed by federal and state regulations. Dangerous goods, as defined by governing regulations, include:

- Explosives (class 1)
- Compressed gases (class 2)
- Flammable liquids (class 3)
- Other flammables, e.g. spontaneously combustible materials (class 4)
- Oxidizers — oxygen sources (class 5)
- Poisonous/toxic substances (class 6)
- Biohazard materials (class 6)
- Radioactive material (class 7)
- Corrosive materials (class 8)
- Miscellaneous hazards, e.g. dry ice and asbestos (class 9)

Any shipment of these items that is to travel over public roads or by air must comply with regulations regarding quantity, packaging, and labeling. The principle regulations are the U.S. Department of Transportation (DOT) (49 CFR 100-185), regulations for shipping hazardous materials. Information can be accessed at <https://www.fmcsa.dot.gov/regulations/hazardous-materials> Department, Laboratory, or Center (DLC) personnel who intend to ship materials by air or land, or convey these items over public roads by Institute or personal vehicles must contact the EHS Office. More details regarding shipping hazardous materials and the EHS Office service can be found on the EHS Website at: <https://ehs.mit.edu/lab-research-program/hazardous-materials-shipping/>

If you plan to ship materials, the EHS Office offers two awareness courses: “Shipping Hazardous Chemicals Awareness” and “Shipping Biohazardous Materials Awareness”. You should select options in the EHS Training Needs Assessment to indicate you may ship hazardous chemicals or biological materials, to assure you are provided the appropriate awareness training. Individuals may register for the courses at <https://ehs.mit.edu/training/>

If you are shipping or receiving chemicals that are not generally found in commerce (i.e. available commercially), you may be subject to additional rules through the EPA Toxic Substances Control Act (TSCA). See Part IV. Section 8. for additional information on TSCA.

If you plan to ship materials to other countries, this will be considered an export, and there are additional requirements you need to meet to assure the materials are properly shipped. More guidance is on the EHS shipping website at: <https://ehs.mit.edu/lab-research-program/hazardous-materials-shipping>

## 10. APPENDICES

### 10.1. Appendix II-A OSHA Permissible Exposure Limits (PELs)

Most SDSs provide PELs for individual chemicals, if a PEL has been established. For a complete list of all PELs, consult the OSHA web site at

[https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9992](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992)

### 10.2. Appendix II-B ACGIH Threshold Limit Values (TLVs)

Most SDSs also provide TLVs for individual chemicals. American Conference of Governmental Industrial Hygienists (ACGIH) TLVs can also be looked up on the National Library of Medicine Toxnet web site at <http://toxnet.nlm.nih.gov/>, (then search the Hazardous Substance Data Bank by individual chemical). A complete list of all ACGIH TLVs is available at the EHS Office (N52-496) or can be purchased at <http://www.acgih.org/home.htm>.

### 10.3. Appendix II-C How to Determine if a Chemical is a Particularly Hazardous Substance

As discussed in Section 3, *particularly hazardous substances* (PHSs) are those chemicals with special acute or chronic hazards. OSHA did not provide a list of PHSs because new chemicals are continually being developed and tested in research laboratories. The OSHA Laboratory Standard provides a definition with which researchers can classify their chemicals to determine which ones have special hazards. OSHA defines PHSs as those chemicals that are select carcinogens, reproductive toxins, or have a high degree of acute toxicity. Details of the definitions and places to obtain information are provided below.

#### 10.3.1. Particularly Hazardous Substance Evaluation of Common Laboratory Chemicals Used at MIT

The first place to look for information on PHSs is on the searchable list *Toxicity Evaluation of Common Laboratory Chemicals Used at MIT*, available from the EHS Office at the Chemical Hygiene Plan website, <https://ehs.mit.edu/chemical-safety-program/dangerous-highly-toxic-chemicals/>. The EHS Office has taken 160 chemicals used widely in MIT laboratories and evaluated them to determine whether they are particularly hazardous. If a chemical is not on the list, it does not mean that it is not a PHS. You then must perform your own determination using the criteria provided below.

#### 10.3.2. Select Carcinogens

Certain potent carcinogens are classified as “select carcinogen” by OSHA and treated as PHSs.

A select carcinogen is a chemical that is:

- ❑ Regulated by OSHA as a carcinogen in a specific standard,
- ❑ Listed as “known to be a carcinogen” or “reasonably anticipated to be a carcinogen” by the National Toxicology Program (NTP), or
- ❑ Listed as “carcinogenic to humans” (Group 1) or “probably or possibly carcinogenic to humans” (Groups 2A and 2B) by the International Agency for Research on Cancer (IARC).

OSHA Carcinogens: A list of all OSHA carcinogens is provided in Part II. Section 3. under Partial List of Select Carcinogens. For more information on any of these chemicals, consult the OSHA web site at <http://www.osha.gov/SLTC/carcinogens/index.html> .

NTP and IARC Carcinogens: The SDS for an individual chemical frequently lists whether the chemical is an NTP or IARC carcinogen. If not provided on the SDS, go to the National Library of Medicine Toxnet web site at <http://toxnet.nlm.nih.gov/> and search the Hazardous Substance Data Bank by individual chemical. The data bank will indicate if the chemical is an NTP or IARC carcinogen. If you want additional information on why these chemicals were classified as confirmed or possible human carcinogens or complete lists of all chemicals evaluated, consult the NTP or IARC web sites. The NTP Annual Report on human carcinogens can be found at: <http://www.ntp.niehs.nih.gov/?objectid=72016262-BDB7-CEBA-FA60E922B18C2540> . The IARC Monographs on human carcinogens can be found at: <http://monographs.iarc.fr/>

#### 10.3.3. Reproductive Toxins



Reproductive toxins are chemicals that adversely affect the reproductive process. These toxins include mutagens that can cause chromosomal damage and teratogens, the effects of which include retarded fetal growth, birth defects, fetal malformations, and fetal death. They also include chemicals that may injure male and female reproductive health.

Knowledge of how chemicals affect reproductive health is in its preliminary stage. It has been only since 1973 that manufacturers were required by the Toxic Substances Control Act (TSCA) to test chemicals other than drugs for their effects on reproductive health. Only a limited number have been tested thoroughly on animals for reproductive effects.

SDSs will often indicate if the chemical has been found to have reproductive health effects. If there is no information on the SDS, the most comprehensive list of reproductive toxins is the chemical list of the State of California's Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65). This list includes chemicals known to the State of California to cause reproductive toxicity and indicates whether it causes female, male, or developmental health effects. The list is available on the web at: <http://www.oehha.org/prop65.html>.

You may also consult general references such as the Catalog of Teratogenic Agents, Seventh Edition, T.H. Shepard, ed., 1992, and other references available in the EHS Office library in N52-496. Please call the Industrial Hygiene Program (617-452-3477) for additional information.

#### 10.3.4. Substances with a High Degree of Acute Toxicity

Acutely toxic substances produce adverse effects when exposed individuals receive only small doses of that substance for a short period of time (hydrogen fluoride, for example). OSHA defines substances that have a high degree of acute toxicity as those "which may be fatal or cause damage to target organs as the results of a single exposure or exposures of short duration."

For many chemicals, the health effects in humans may not have been tested. Frequently, only basic animal testing has been done, such as the LD<sub>50</sub> or the LC<sub>50</sub>. The LD<sub>50</sub> is the Lethal Dose that kills 50 percent of the animals when the chemical is given orally or applied to the skin. The LC<sub>50</sub> is the Lethal Concentration in air that kills 50 percent of the animals.

OSHA has given dose criteria for substances of high acute toxicity based on LD<sub>50</sub> and LC<sub>50</sub> animal tests as follows:

##### Compounds with High Degree of Acute Toxicity:

TEST	TOXIC	HIGHLY TOXIC
Oral LD <sub>50</sub> (albino rats)	50-500 mg/kg	<50 mg/kg
Skin Contact LD <sub>50</sub> (albino rabbits)	200-1000 mg/kg	<200 mg/kg
Inhalation LC <sub>50</sub> (albino rats)	200-2000 ppm in air	<200 ppm in air
Probable Equivalent Lethal Oral Dose for Humans (for 70 kg or 150 lb person)	<35 g (about 1 oz or 2 tablespoons)	<3.5 g (about 1/10 oz or 1/2 teaspoon)

Note: both "toxic" and "highly toxic" chemicals in the table above are considered by OSHA to have a high degree of acute toxicity, and therefore are *particularly hazardous substances*.

Animal toxicity test results are often presented in SDSs. If not provided on the SDS, go to the National Library of Medicine Toxnet web set at <http://toxnet.nlm.nih.gov/> and search the Hazardous Substance Data Bank by individual chemical. Under your chemical, select "Animal Toxicity Studies" and then "Non-Human Toxicity Values" from the table of contents to obtain LD<sub>50</sub> and LC<sub>50</sub> test results.

### Select Toxins

As a result of requirements of the U.S. Patriot Act, the U.S. Department of Health and Human Services (DHHS) and the U.S. Department of Agriculture (USDA) have identified a select group of biologically-derived toxins, which are considered particularly hazardous because of their acute toxicity. They have enacted regulations pertaining to these agents when they are present in amounts above regulatory threshold quantities. These agents and the threshold quantities are provided in the tables below.

<b>Toxin</b>	<b>DHHS Toxins Regulatory Threshold Quantity Requiring CDC Certificate of Registration</b>
Abrin	100 mg
Contoxins	100 mg
Diacetoxyscirpenol	1000 mg
Ricin	100 mg
Saxitoxin	100 mg
Tetrodotoxin	100 mg
Shiga-like ribosome inactivating proteins	100 mg

### Overlap Toxins (DHHS and USDA)

<b>Toxin</b>	<b>Regulatory Threshold Quantity Requiring CDC or USDA Certificate of Registration</b>
Botulinum neurotoxins	0.5 mg
Clostridium perfringens epsilon toxin	100 mg
Shigatoxin	100 mg
Staphylococcal enterotoxins	5 mg
T-2 toxin	1000 mg

Please see Part II. Section 3.4 for MIT requirements for ordering, use and storage of these biotoxins to ensure that the Institute as a whole does not exceed threshold quantities, and to ensure that the Institute manages these biotoxins safely.

Please note also that there are other biotoxins such as aflatoxins and picotoxin that are not regulated under DHHS and USDA, but that would be considered PHSs because they meet the definition of acute toxicity. Appropriate precautions should be taken when handling these biotoxins, as well as other biotoxins not mentioned because, as a class of chemical, they are usually highly toxic.

#### 10.3.5. Substances with Unknown Toxicity

New substances used in laboratories frequently have not been tested for their acute, carcinogenic, or reproductive toxicity. These compounds should be used with the utmost caution and generally handled as if they are particularly hazardous substances. For example, a laboratory working with chemicals it knows to be potent mutagens, but which have not yet been screened for carcinogenic or reproductive effects, may choose to consider these chemicals PHSs and handle them accordingly.

## PART III. MRL Specific Chemical Hygiene Practice or Lab Specific Standard Operating Procedures

### 1. INTRODUCTION

This Part contains policies, procedures or precautions that are required by MRL. This section contains procedures developed for specific laboratories, experiments or operations. A template for developing Lab Specific SOPs is included in this Part to provide assistance to laboratory personnel generating specific safety procedures for their lab.

Additional Lab Specific SOPs must be developed for any operation or hazardous material for which the general safety procedures contained in Part II. of this Chemical Hygiene Plan are inadequate to address hazards. These procedures must be written to clearly identify additional or special precautions, controls, personal protective equipment and emergency procedures that are required, as well as the nature of the hazards the procedure is intended to minimize. Each Lab Specific SOP must be reviewed by the PI and the DLC Chemical Hygiene Officer (CHO). EHS is available to assist with development or review of Lab Specific SOPs as well.

A Lab Specific SOP that addresses the requirements noted above must be documented and maintained in the laboratory and it is suggested the SOP be included in Part III. of this Chemical Hygiene Plan. A Lab Specific SOP template is provided in Appendix III-A, paragraph 4 below, to facilitate Lab Specific SOP development. Instructions regarding use of the SOP template are contained in the following section.

### 2. MRL Standard Operating Procedures

MRL-Specific Standard Operating Procedures (SOP)

This section contains procedures developed for specific laboratories, experiments or operations.

#### 2.1 Special Handling Procedures for Some Common Particularly Hazardous Substances

This section outlines special handling procedures for some specific compounds that may be classified as particularly hazardous substances as they are used in MRL laboratories. The information presented in this section is not meant to be complete, and researchers should consult the appropriate literature and their Laboratory Supervisor before working with these particularly hazardous substances.

##### **a. Acrylonitrile**

Acrylonitrile is regulated as a probable human carcinogen by OSHA and is also listed as a substance with a moderate degree of acute toxicity (oral LD<sub>50</sub> (rat) is 78 mg/kg). The permissible exposure limit (PEL) is 2 ppm; the threshold limit value - time-weighted average (TLV-TWA) is also 2 ppm. Acrylonitrile is severely irritating to the eyes and mildly irritating to the skin; prolonged contact with the skin can lead to burns. Acrylonitrile is a highly flammable liquid; its vapor forms explosive mixtures with air. **Work involving significant quantities of acrylonitrile should be conducted using the general procedures outlined in both Parts II-C.3 and II-E.3.** In particular, work with acrylonitrile should be conducted in a fume hood to prevent exposure by inhalation; splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact.

##### **b. Benzene**

Exposure to benzene can lead to both chronic and acute toxic effects. The acute toxic effects from skin contact, inhalation, or ingestion of benzene are low. In humans, acute inhalation exposure to benzene can produce a picture of acute delirium, characterized by excitement, euphoria, and restlessness and, if the exposure is significantly high, the symptoms may progress to depression, drowsiness, stupor, and even unconsciousness. The concentration required to produce this symptom complex is 1000 ppm or higher. These concentrations will also irritate the eyes, nose, and respiratory tract.

Chronic inhalation exposure to 25-50 ppm of benzene can produce changes in the blood that include macrocytosis, decrease in the total red blood count, decrease in platelets, decrease in the hemoglobin concentration, or decrease in leukocytes. Any or all of these hematologic effects may be seen in any

individual. Usually, the worker will be asymptomatic while these effects are observed in the blood picture. Continued exposure at somewhat higher concentrations (probably more than 100 ppm) may result in more severe blood disorders that include leukopenia or even aplastic anemia, with symptoms of headaches, dizziness, loss of appetite, nervousness, irritability, and perhaps bleeding manifestations (i.e., nosebleeds, easy bruising, or hematuria). Severe cases may have fatal outcomes. Recently, a number of reports have been published that describe leukemia in workers who have had aplastic anemia. These cases have been reported in Italy and Turkey in workers exposed to grossly high concentrations of benzene. In addition, there is some indication that an excess of leukemia may occur without a preceding diagnosis of aplastic anemia in workers who have been repeatedly exposed to benzene at concentrations of more than 100 ppm.

The current OSHA permissible exposure limit (PEL) for benzene is 1 ppm as an 8-hour time-weighted average (TWA), and the Short Term Exposure Limit (STEL) is 5 ppm as an average for any 15-minute period. The ACGIH TLV-TWA value is 0.5 ppm. Benzene is a flammable liquid and should not be exposed to heat or flame. An explosion hazard also exists when its vapors are exposed to flame. Benzene may react vigorously with oxidizing agents such as bromine pentafluoride, chlorine, chromic acid, nitryl perchlorate, oxygen, ozone, perchlorates, aluminum chloride plus fluorine perchlorate, sulfuric acid plus permanganates, potassium peroxide, silver perchlorate plus acetic acid, and sodium peroxide.

**Experiments involving the use of significant quantities of benzene should be conducted employing the general procedures outlined in Part II-C.3; all operations in which there is the possibility of the accidental release of harmful quantities of benzene should be carried out in a designated area.**

**c. Bis(chloromethyl)ether (BCME), Chloromethyl Methyl Ether, and Other Chloromethyl Ether Derivatives**

Because of the high volatility of bis(chloromethyl)ether (BCME), inhalation is the route of exposure that presents the greatest hazard to humans. BCME vapor is severely irritating to the skin and mucous membranes and can cause corneal damage that heals slowly. The substance has caused lung cancer in humans. BCME is highly toxic to animals via inhalation: LD<sub>50</sub> (rats, 7-hour inhalation) = 7 ppm. It is moderately toxic via the oral and skin routes: LD<sub>50</sub> (rats, oral) = 280 mg/kg; LD<sub>50</sub> (rabbits, skin) = 368 mg/kg. Its vapors strongly irritate the eyes of rats. Rats and hamsters subjected to 10 or 30 6-hour exposures of 1 ppm BCME showed evidence of tracheal and bronchial hyperplasia, as well as effects on the central nervous system. BCME is carcinogenic to mice following inhalation, skin application, or subcutaneous administration. In newborn mice, it is carcinogenic by inhalation and subcutaneous administration. BCME is a lung carcinogen in humans.

The threshold limit value (TLV) for BCME is 0.001 ppm (1 ppb; 5 ug/m<sup>3</sup>). The substance is classified by ACGIH as a human carcinogen. OSHA has classified BCME as a cancer-suspect agent and has stringent regulations (29 CFR 1910.1008) for its use if its concentration exceeds 0.1%. **Work involving chloromethyl ether derivatives must be carried out using the general procedures outlined in Parts II-C.3 and II-E.3.**

**d. Carbon Monoxide**

Carbon monoxide is a direct and cumulative poison. It combines with the hemoglobin of the blood to form a relatively stable compound (carboxyhemoglobin), rendering it useless as an oxygen carrier. When about one-third of the hemoglobin has entered into such combination, the victim dies. Since carbon monoxide is odorless, colorless, and tasteless, it has no warning properties. Exposure to 1500-2000 ppm CO in air for 1 hour is dangerous, and exposure to 4000 ppm is fatal in less than 1 hour. Headache and dizziness are the usual symptoms of CO poisoning, but occasionally the first evidence of poisoning is the collapse of the patient. Pregnant women are more susceptible to the effects of carbon monoxide exposure.

**Carbon monoxide should be used only in areas with adequate ventilation employing the general procedures outlined in Part II-C.3.** A trap or vacuum break should always be used to prevent impurities from being sucked back into a CO cylinder.

#### **e. Carbon Tetrachloride**

The current OSHA permissible exposure limit (PEL) for carbon tetrachloride is 10 ppm as an 8-hour time-weighted average and 25 ppm as a ceiling for any period of time provided the 8-hour average is not exceeded. The ACGIH TLV-TWA is 5 ppm, and the STEL is 10 ppm as the maximum concentration for any 15-minute period. ACGIH states that skin contact may account for a substantial part of toxic responses.

The acute toxicity of carbon tetrachloride by all routes of exposure is low to moderate (oral LD<sub>50</sub> in rats is 2,350 mg/kg). Carbon tetrachloride shows carcinogenic effects in animal studies and is listed in group 2B ("possible human carcinogen") by IARC. **It need not be treated as a particularly hazardous substance in most of its uses in MRL laboratories.** In cases where large quantities of carbon tetrachloride are in frequent use, then the general procedures outlined in Part II-C should provide adequate protection. All operations should be carried out in a hood, not only because of the carcinogenicity of the substance, but also because of its other toxic effects (e.g., hepatotoxicity) and its volatility. Nitrile rubber is the recommended material for gloves and other protective clothing.

#### **f. Chlorine**

Chlorine is a severe eye, skin, and mucous membranes irritant. Inhalation may cause coughing, choking, nausea, vomiting, headache, dizziness, difficulty breathing, and delayed pulmonary edema, which can be fatal. Exposure to ca. 500 ppm for 30 minutes may be fatal and 1000 ppm can be lethal after a few breaths. Chlorine is highly irritating to the eyes and skin; exposure to 3-8 ppm causes stinging and burning of the eyes, and contact with liquid chlorine or high concentrations of the vapor may cause severe burns. Chlorine can be detected by its odor below the permissible limit; however, because of olfactory fatigue, odor may not always provide adequate warning of the presence of harmful concentrations of this substance. There is no evidence for carcinogenicity or reproductive or developmental toxicity of chlorine in humans. The LC<sub>50</sub> for inhalation (rat) is 293 ppm (1 h); the permissible exposure limit (PEL) is 1 ppm as a ceiling concentration, while the threshold limit value - time-weighted average (TLV-TWA) is 0.5 ppm.

Chlorine is noncombustible but is a strong oxidizer and will support combustion of most flammable substances, sometimes with explosive violence. Cylinders of chlorine should be stored in locations appropriate for compressed gas storage and separated from incompatible compounds such as hydrogen, acetylene, ammonia, and flammable materials. Because of its high toxicity, **laboratory operations using chlorine must be carried out in a hood employing the general procedures outlined in Part II-C.**

#### **g. Chloroform**

The acute toxicity of chloroform is classified as moderate by ingestion and low by inhalation. Inhalation exposure to chloroform at concentrations greater than 1000-ppm can cause dizziness, nausea, and headaches. At higher concentrations, there may be disorientation and delirium progressing to unconsciousness. Such high exposure can also produce liver and possibly kidney damage. It is believed that chloroform can sensitize the heart to adrenaline, so it may cause cardiac arrhythmias and possibly death. High concentrations of the vapor can produce conjunctivitis. Liquid chloroform in the eyes produces a painful corneal injury that usually heals in several days.

Chronic exposure to chloroform at concentrations of 100-200 ppm has been reported to produce large livers. Continued contact with the skin can produce drying, fissuring, and inflammation. In experimental studies, prolonged ingestion of high levels of chloroform by mice resulted in liver cancers and kidney tumors in rats. Chloroform produced embryo toxicity in experimental animals. It is a suspected human carcinogen.

Although the fire hazard of chloroform is slight, exposure to heat or flame can generate phosgene gas. Chloroform reacts violently with acetone in the presence of base, and with aluminum, disilane, lithium, magnesium, nitrogen tetroxide, potassium, perchloric acid plus phosphorus pentoxide, potassium hydroxide plus methanol, potassium tert-butoxide, sodium, sodium hydroxide plus methanol, sodium methylate, and sodium hydride.

The current OSHA permissible exposure limit (PEL) for chloroform is 50 ppm as a ceiling level that should not be exceeded for any 15-min period. The ACGIH currently recommends that chloroform be treated as a suspect human carcinogen and recommends an 8-hour time weighted average exposure of 10 ppm.

Although chloroform has caused tumors in animals, its potency is low. **It need not be treated as a particularly hazardous substance in most of its uses in the MRL.** In cases where significant quantities of chloroform are in frequent use, the general procedures outlined in Part II-C should provide adequate protection. The high volatility of chloroform emphasizes the importance of a hood for such operations. Polyvinyl alcohol gloves provide the best hand protection.

#### **h. Dimethyl and Diethyl Sulfate (DMS)**

Many cases of dimethyl sulfate poisoning have been reported. The common initial symptoms are headache and giddiness, with burning eyes. The patient's condition may worsen with painful eyes, nose and throat irritation, loss of voice, coughing, difficulty breathing and swallowing, vomiting, and possible diarrhea. The onset of the symptoms may be delayed for up to 10 hours. This substance is extremely hazardous because of its lack of warning properties and its delayed toxic effects. Skin contact causes blistering and necrosis, and DMS can be absorbed through the skin in sufficient quantity to cause systemic intoxication. In the worst cases, there is severe inflammation of the mucous membranes a pulmonary injury that may be fatal; several deaths have occurred. For example, exposure to 97 ppm for 10 min was fatal. DMS is moderately toxic to animals via oral route: LD<sub>50</sub> (rats) = 440 mg/kg. Undiluted DMS produced moderate to severe irritation when applied to the skin of guinea pigs; 1% DMS produced mild irritation. DMS does not cause skin sensitization in animals. Undiluted DMS applied to rabbit eyes produced severe injury. Even a 1-hour exposure to 58 ppm has resulted in permanent eye damage in rats. During a 4-hour exposure, 30 ppm DMS killed five out of six rats, but 15 ppm was not lethal.

DMS has been shown to be a rat carcinogenic by inhalation, subcutaneous injection, and following 1 hour per day exposures to 10 ppm DMS for 130 days. The threshold limit value (TLV) for DMS is 0.1 ppm (0.5 mg/m<sup>3</sup>) as an 8-hour time-weighted average. DMS is classified as being suspected of carcinogenic potential in humans by the ACGIH. The OSHA permissible exposure limit (PEL) for DMS is 1.0 ppm. These limits include a warning of the potential contribution of skin absorption to the overall exposure.

**The general procedures outlined in Part II-E should be used when handling more than a few grams of DMS in view of its fairly high carcinogenic potency in rats by inhalation and its ability to penetrate the skin.** It is particularly important to avoid skin contact by using the appropriate rubber gloves, a rubber apron, and other protective apparel, and to avoid inhalation of even low concentrations of vapor by working in a hood. Operations involving smaller quantities of DMS can be conducted using the general procedures presented in Part II-C.

#### **i. Ethylene Dibromide (1,2-Dibromoethane)**

Ethylene dibromide (EDB) is classified as a compound with a moderate degree of acute toxicity; the approximate oral lethal dose of EDB for humans is 5-10 mL. Skin absorption of EDB can also cause death, and inhalation of the vapor can produce pulmonary edema. EDB can cause severe irritation to all exposed tissues, respiratory tract, skin, and eye. Systemic effects include central nervous system depression, kidney injury, and severe liver necrosis. Ethylene dibromide is highly toxic to animals via inhalation. The maximum survival exposure of rats to EDB vapors in air is 3000 ppm for 6 min, 400 ppm for 30 min, and 200 ppm for 2 hours. It is moderately toxic via the oral and skin routes: LD<sub>50</sub> (rats,

oral) = 108 mg/kg; LD<sub>50</sub> (rabbits, skin) = 300 mg/kg. EDB is markedly irritating to skin, and a 10% solution has caused serious but reversible corneal injury in rabbit eyes. Rats were repeatedly exposed to 50 ppm EDB for 6 months. Half died from pneumonia and upper respiratory tract infections. Slight changes in the liver and kidney were seen. EDB has induced a high incidence of tumors (squamous-cell carcinomas of the fore-stomach) in mice and rats following oral administration. The 1979 threshold limit value (TLV) for EDB was 20 ppm (155 mg/m<sup>3</sup>) as an 8-hour time-weighted average. The short-term exposure limit was 30 ppm over any 15-min period. These limits include a warning about the potential contribution of skin absorption to the overall exposure. In 1980, the ACGIH put EDB in category A 1b (human carcinogen). For this category, there is no TLV assigned, but the ACGIH recommends that those working with A-1.b carcinogens should be properly equipped to ensure virtually no contact with the carcinogens. Currently, there is no TLV assigned for EDB. The OSHA permissible exposure limit (PEL) for EDB is 20 ppm, and the acceptable maximum peak is 50 ppm for 5 min in any 8-hour time period.

On the basis of the carcinogenicity data for EDB, **the procedures described in Part II-E should be followed when handling more than a few grams in the laboratory.** Operations involving smaller quantities can be carried out using the procedures outlined in Part II-C. Serious skin injury can occur from direct exposure to EDB. The substance can penetrate neoprene and several other types of plastic; therefore, gloves and other protective apparel made of these materials provide only temporary protection against EDB spills.

#### **i. Hydrazine**

Hydrazine is classified as a compound with a high degree of acute toxicity; vapor exposure can cause respiratory tract irritation, excitement, convulsion, cyanosis, and decrease in blood pressure. The liquid can severely burn the eyes and skin. Hydrazine can cause fatty degeneration of the liver, nephritis, and hemolysis. Hydrazine also poses a dangerous fire and explosion risk and can explode during distillation if traces of air are present. Hydrazine is moderately toxic to animals via the inhalation, oral, and skin routes: LC<sub>50</sub>(rats, 4-hour inhalation) = 570 ppm; LD<sub>50</sub> (rats, oral) = 60 mg/kg; LD<sub>50</sub>(rabbits, skin) = 283 mg/kg (hydrazine hydrate). It is a strong skin and mucous membrane irritant and a strong skin sensitizer. Hydrazine hydrate produced moderately severe irritation when applied to rabbit eyes. After repeated oral, skin, or injection exposure, the effects noted include weight loss, weakness, vomiting, and convulsions. The chief histological finding is fatty degeneration of the liver. Among guinea pigs and dogs exposed to hydrazine in the air 5-47 times, the dogs showed liver damage, with lesser damage to the kidneys and lungs, while the guinea pigs had pneumonitis and partial lung collapse. Hydrazine is not regarded as having adequate warning properties.

Hydrazine and hydrazine salts are known to be carcinogenic in mice after oral and intraperitoneal administration and in rats following oral dosing. By the oral route, effects were found at doses of 24-36 (mg/kg)/day in mice and 20 (mg/kg)/day in rats. No tumors were observed in Syrian golden hamsters after oral administration. The ACGIH has classified hydrazine as suspected of carcinogenic potential in humans. The threshold limit value (TLV) for hydrazine is 0.01 ppm (0.013 mg/m<sup>3</sup>) and the OSHA permissible exposure limit (PEL) is 1.0 ppm (1 mg/m<sup>3</sup>) as 8-hour time-weighted averages. These limits include a warning about the potential contribution of skin absorption to the overall exposure. NIOSH has (1978) recommended a ceiling limit of 0.03 ppm in any 2-hour period.

**When more than a few grams of hydrazine are to be used in the laboratory, the general procedures outlined in both Parts II-C.3 and II-E should be used** because hydrazine is carcinogenic in animal tests, quite volatile, and readily absorbed through the skin. Nitrile rubber is recommended for gloves and other protective apparel. Prompt washing with water effectively removes hydrazine from skin that it has splashed on. Hydrazine should not be used in the vicinity of a flame or under conditions where sparks can occur, as an explosion or fire can result.

#### **k. Hydrogen Bromide and Hydrogen Chloride**

Both hydrogen bromide (HBr) and hydrogen chloride (HCl) are toxic gases that are severely irritating to the upper respiratory tract. The acids formed neutralize the alkali of the tissues and can cause death as a result of edema or spasm of the larynx and inflammation of the upper respiratory system. Concentrations of 0.13-0.2% are lethal for human beings in exposures lasting a few minutes. However, because of their odor, these gases usually provide adequate warning for prompt voluntary withdrawal from contaminated atmospheres. These gases are also corrosive to the skin and mucous membranes and can cause severe burns. Exposure to high concentrations may also result in dermatitis. Contact with the eyes rapidly causes severe irritation of the eyes and eyelids.

Hydrogen bromide and hydrogen chloride are corrosive gases that have pungent, irritating odors, detectable at 2 ppm for HBr and at 0.25-10 ppm for HCl. The OSHA PEL for HBr is 3 ppm and is 5 ppm for HCl, both of which are ceiling limits. The irritating odor of these substances provides adequate warning. Although both are colorless, they fume in moist air because of their high solubility in water. In a cylinder under pressure, both exist in the form of a gas over a liquid (under such conditions, the cylinder pressure is equal to the vapor pressure of the substance contained; at 25 °C, this is 4.22 MPa (613 lb/in.<sup>2</sup>) for HCl and 2.20 MPa (320 lbf/in.<sup>2</sup>) for HBr). As long as liquid is present in the cylinder, the pressure will remain fairly constant. Although neither HBr nor HCl is combustible, both react with common metals to form hydrogen, which may form explosive mixtures with air.

**Operations involving significant quantities of hydrogen bromide and hydrogen chloride should be conducted using the general procedures outlined in Part II-C.3.** Laboratory workers should wear protective apparel, including rubber gloves, suitable gas-tight chemical safety goggles, and clothing such as a rubber or plastic apron. Proper respiratory equipment should be available. These gases should be handled only in adequately ventilated areas. A check valve, vacuum break, or trap should always be used to prevent foreign materials from being sucked back into the cylinder because this can cause the development of dangerous pressures. Leaks of HBr or HCl will be evident by the formation of dense white fumes on contact with the atmosphere. Small leaks of HCl can be detected by holding an open bottle of concentrated ammonium hydroxide near the site of the suspected leak; the formation of dense white fumes confirms the existence of a leak. Cylinder-valve leaks can usually be corrected by tightening the valve packing nut (by turning it clockwise as viewed from above).

#### **I. Hydrogen Cyanide**

**Prior approval from the MRL Director is required before using hydrogen cyanide (see Part II-F).**

#### **m. Hydrofluoric Acid**

**The use of anhydrous hydrogen fluoride requires prior approval from the MRL Director.**

All forms—dilute or concentrated solutions or the vapor—of hydrofluoric acid (HF) cause severe burns. Inhalation of anhydrous HF or HF mist or vapors can cause severe respiratory tract irritation that may be fatal. Death from pulmonary edema occurred within 2 hours in three of six workers splashed with 70% HF solution despite prompt showering with water. Anhydrous HF is a clear, colorless liquid that boils at 19.5 °C. Because of its low boiling point and high vapor pressure; anhydrous HF must be stored in pressure containers. A 70% aqueous solution is a common form of HF. Hydrofluoric acid is miscible with water in all proportions and forms an azeotrope (38.3% HF) that boils at 112 °C. Anhydrous or concentrated aqueous HF causes immediate and serious burns to any part of the body. Dilute solutions (<30%) and gaseous HF are also harmful; although several hours may pass before redness or a burning sensation is noticed. These burns may still be quite severe and progressively damage the skin and deeper tissues. "Undissociated HF readily penetrates skin and deep tissue where the corrosive fluoride ion can cause necrosis of soft tissues and decalcification of bone; the destruction produced is excruciatingly painful. Fluoride ion also attacks enzymes (e.g., of glycolysis) and cell membranes. The process of tissue destruction and neutralization of the hydrofluoric acid is prolonged for days, unlike other acids that are rapidly neutralized. Because of the insidious manner of penetration, a relatively mild or minor exposure can cause a serious burn" [Proctor, N. H.; Hughes, J. P.; Fischman, M. L. *Chemical Hazards of the Workplace*, J. B. Lippincott Co., Philadelphia, 1988, p. 279]. Occasionally workers fail to recognize the importance of seeking medical attention for HF burns **before** pain commences. By the time the victim is affected with progressively deep and more painful throbbing and burning, serious damage may have taken place. Exposures under fingernails can be a particularly



painful problem if ignored. Wearing clothing (including leather shoes and gloves) that has absorbed small amounts of HF can result in serious delayed effects such as painful slow-healing skin ulcers.

It is crucial to ensure adequate ventilation by working only in a hood so that safe levels (3 ppm) are not exceeded when handling HF. All contact with the liquid vapor with the eyes, skin, respiratory system, or digestive system must be avoided by using protective equipment such as a face shield and neoprene or polyvinyl chloride gloves. The protective equipment should be washed after each use to remove any HF on it. Safety showers and eyewash fountains should be nearby. Anyone working with HF should have received prior instructions about its hazards and should know the proper protective measures for treatment in the event of exposure (Reinhardt, C.F. et al.; *Am. Ind. Hyg. Assn. J.*, **1966**, 27, 166).

1. Spills and leaks – The vapors of both anhydrous HF and aqueous 70% HF produce visible fumes if they contact moist air. This characteristic can be useful in detecting leaks but cannot be relied on because of atmospheric variations. Spills of HF must be treated immediately to minimize the dangers of vapor inhalation, body contact, corrosion of equipment, and possible generation of hazardous gases. Spills should be contained and diluted with water. Neutralize the resulting solution with lime before disposal.
2. Neutralization – To neutralize, HF should be slowly added to a larger volume of a stirred solution of slaked lime to precipitate calcium fluoride, which is chemically inert and poses little toxic hazard (sodium fluoride is highly soluble and toxic). Alternatively hydrofluoric acid can be diluted to about 2% concentration with cold water in a polyethylene vessel, neutralized with aqueous sodium hydroxide, and treated with excess calcium chloride solution to precipitate calcium fluoride.
3. In the event of exposure – Anyone who knows or even suspects that he or she has come into direct contact with HF should immediately flush the exposed area with large quantities of cool water. Exposed clothing should be removed as quickly as possible while flushing. Medical attention should be obtained promptly, even if the injury appears slight. On the way to the physician, the burned area should be immersed in a mixture of ice and water. If immersion is impractical, a compress made by inserting ice cubes between layers of gauze should be used. Make sure that the physician understands that the injury was caused by HF and requires treatment very different from other acid burns. Even in the case of very small exposure, washing alone may not be sufficient to completely prevent injury. For minor exposures such as small hole in a glove, application of a calcium gluconate antidote gel can bind free fluoride ion not removed by washing. Regular HF users may obtain this gel by contacting the EHS Office (452-3477).

If HF liquid or vapor has contacted the eyes, these organs should be flushed with large quantities of clean water while the eyelids are held apart. This flushing should be continued for 15 minutes. Medical attention should be obtained promptly.

Anyone who has inhaled HF vapor should be removed immediately to an uncontaminated atmosphere and kept warm. Medical help should be obtained promptly. Anyone who has ingested HF should drink a large quantity of water as quickly as possible. **Do not induce vomiting; promptly obtain medical help.** After the acid has been thoroughly diluted with water, if medical attention is delayed, the person should be given milk or two fluid ounces of milk of magnesia to drink to sooth the burning effect.

#### **n. Hydrogen Sulfide**

The acute toxicity of hydrogen sulfide by inhalation is moderate. A five-minute exposure to 800 ppm has resulted in death. Inhalation of 1000 to 2000 ppm may cause coma after a single breath. Exposure to lower concentrations may cause headache, dizziness, and nausea. Low concentrations (20-150 ppm) of hydrogen sulfide can cause eye irritation which may be delayed in onset. Although the odor of hydrogen sulfide is detectable at very low concentrations (below 0.1 ppm), it rapidly causes olfactory fatigue at higher levels, and therefore is not considered to have adequate warning properties. Hydrogen sulfide has not been shown to be carcinogenic or to have reproductive or developmental effects in humans. The hydrogen sulfide LC<sub>50</sub> for inhalation (rat) is 444 ppm; the permissible exposure limit (PEL) **ceiling** is 20 ppm, and the threshold limit value - time-weighted average (TLV-TWA) is 10 ppm.

Hydrogen sulfide is flammable in air, and the combustion products are also toxic by inhalation. It is incompatible with strong oxidizers, will attack many metals, some plastics and rubbers, and reacts violently with a variety of metal oxides. **Laboratory operations with hydrogen sulfide should be carried out in a hood using the general procedures outlined in Part II-C.3.** In particular, cylinders of hydrogen sulfide should be stored and used in a continuously ventilated gas cabinet or fume hood.

**o. Nickel Carbonyl**

**The use of nickel carbonyl requires prior approval from the MRL Director.**

**p. Nitrogen Dioxide**

Nitrogen dioxide (NO<sub>2</sub>) is classified as a highly acute toxin; it is a primary irritant, acting principally on the lungs and to a lesser extent on the upper respiratory tract. It is certainly one of the most insidious of the gases. The inflammation of the lungs may cause only slight pain, but the edema that results may easily cause death. Toxic effects may develop after a 10-minute exposure to 10 ppm, and 100 ppm of NO<sub>2</sub> in air is a dangerous concentration for even a short exposure. Exposure to 200 ppm for 1-2 min may be fatal.

Nitrogen dioxide gas is reddish brown, has an irritating odor, and must be avoided by the use of an air-purifying respirator equipped with an acid-gas cartridge or canister; at concentrations greater than 50 times the threshold limit value (TLV), which is 3 ppm as an 8-hour TWA), a positive-pressure atmosphere-supplying respirator must be used and, in IDLH atmospheres, a pressure-demand self-contained breathing apparatus or a positive-pressure air-line respirator that has escape-cylinder provisions is required.

**Nitrogen dioxide should be handled using the general procedures outlined in Part II-C.3 and II-E.** Nitrogen dioxide is a deadly poison, and no one should work with a cylinder of this substance unless they are fully familiar with its handling and its toxic effect. Ventilation is extremely important, and respiratory protective equipment should always be available. Only stainless steel fittings should be used.

**q. Mercury**

The element mercury is a liquid metal with a vapor pressure of 0.00185 mm at 25 °C. This corresponds to a saturation concentration of 20 milligrams of mercury per cubic meter of air or 2.4 parts per million of air. The American Conference of Governmental Industrial Hygienists has established a threshold limit for mercury vapor of 0.025 milligrams of mercury per cubic meter of air for continuous 40-hour per week exposure. Long-term chronic exposure to mercury vapor in excess of 0.025 mg of mercury per cubic meter of air may result in cumulative poisoning. The use of mercury in laboratory amounts in well-ventilated areas is fairly safe; however special precautions must be followed when working with large quantities of mercury.

Mercury poisoning from exposure by chronic inhalation produces a variety of symptoms. The characteristic effects are emotional disturbances, unsteadiness, inflammation of the mouth and gums, general fatigue, memory loss, and headaches. Kidney damage may result from poisoning by mercurical salts. In most cases of exposure by chronic inhalation, the symptoms of poisoning gradually disappear when the source of exposure is removed. However, improvement may be slow and complete recovery may take years. Skin contact with mercury compounds produces irritation and various degrees of corrosion. Soluble mercury salts can be absorbed through the intact skin and produce poisoning.

**The general procedures outlined in Part II-C.3 should be followed when working with large quantities of liquid mercury.** Every effort should be made to prevent spills of metallic mercury because the substance is extremely difficult and time consuming to pick up. Droplets get into cracks and crevices, under table legs, and under and into equipment. If spills are frequent and Hg is added to the general air level, the combined concentration may exceed the allowable limits.

- **Storage** – Containers of large quantities of mercury should be kept closed and stored in secondary containers in a well-ventilated area. When breakage of instruments or apparatus containing mercury is a possibility, the equipment should be placed in an enameled or plastic tray or pan that can be cleaned easily and is large enough to contain the mercury in the event of accident. Transfers of Hg from one container to another should be carried out in a hood, over a tray or pan to confine any spills.
- **Cleanup of spills** – Pools of metallic Hg can be collected by suction by using an aspirator bulb or a vacuum device made from a filtering flask, a rubber stopper, and several pieces of flexible rubber and glass tubing. Alternatively, mercury-spill cleanup kits are available commercially. When a large spill, pressure system rupture, or heating of mercury is involved, the EHS Office (452-3477) will survey the area and advise on the degree of hazard which may exist and necessary preventive measures to be undertaken. A special "mercury vacuum cleaner" may be borrowed from the EHS Office (452-3477) for use in cleaning up large spills. If Hg has spilled on the floor, the workers involved in cleanup and decontamination activities should wear plastic shoe covers. When the cleanup is complete, the shoe covers should be disposed of and the workers should thoroughly wash their hands, arms, and face several times.
- **Waste Disposal** – Significant quantities of metallic Hg from spills or broken thermometers or other equipment, and contaminated Hg from laboratory activities should be collected in thick-walled high-density polyethylene bottles for reclamation. Rags, sponges, shoe covers, and such used in cleanup activities, and broken thermometers containing small amounts of residual mercury, should be placed in a sealed plastic bag, labeled, and disposed of in a safe manner.

**r. N-Nitrosodialkylamines and Certain Other N-Nitroso Compounds**

N-Nitrosodimethylamine is strongly hepatotoxic and causes death from liver insufficiency in experimental animals. It is carcinogenic in at least 10 animal species, and is regarded to be a probable human carcinogen. The main targets for its carcinogenic activity are the liver, lung, esophagus, trachea, and nasal cavity. Although data are not available on the toxicity of N-nitrosodiethylamine in humans, the closely related compound N-nitrosodimethylamine has caused extensive liver damage as a consequence of ingestion, inhalation, or topical application to the skin. It is prudent to regard other nitrosamine derivatives as being potential carcinogens.

**The general procedures outlined in Parts II-C.3 and Part II-E should be followed when working with N-nitrosodialkylamines.** All work with N-nitrosodialkylamines should be carried out in a well-ventilated hood or in a glove box equipped with a HEPA filter. To the extent possible, all vessels that contain N-nitrosodialkylamines should be kept closed. All work should be carried out in apparatus that is contained in or mounted above unbreakable pans that will contain any spill. All containers should bear a label such as the following: CANCER-SUSPECT AGENT. All personnel who handle the material should wear plastic, latex, or neoprene gloves and a fully buttoned laboratory coat.

1. **Storage** – All bottles of N-nitrosodialkylamines should be stored and transported within an unbreakable outer container; storage should be in a ventilated storage cabinet (or in a hood).
2. **Cleanup of spills and waste disposal** – Because N-nitrosodialkylamines are chemically stable under usual conditions, disposal is best carried out by incineration. Contact the EHS Office to arrange for the disposal of waste and contaminated materials. For incineration of liquid wastes, solutions should be neutralized if necessary, filtered to remove solids, and put in closed polyethylene containers for transport. All equipment should be thoroughly rinsed with solvent, which should then be added to the liquid waste for incineration. Great care should be exercised to prevent contamination of the outside of the solvent container. If possible, solid wastes should be incinerated; if this is not possible, solid wastes from reaction mixtures that may contain N-nitrosodialkylamines should be extracted and the extracts added to the liquid waste. Similarly, any rags, paper and such that may be contaminated should be incinerated. Contaminated solid materials should be enclosed in sealed plastic bags that are labeled CANCER-SUSPECT AGENT with the name and amount of the carcinogen. The bags should be stored in a well-ventilated area until incineration. Spills of N-nitrosodialkylamines can be absorbed by Celite R or a commercial spill absorbant. After the absorbant containing the major share of the nitrosamine has been picked up (avoid dusts; do not sweep), the surface should be thoroughly cleaned with a strong detergent solution. If a major spill occurs outside of a ventilated area, the room should be

evacuated, the EHS Office (452-3477) should be contacted and the cleanup operation should be carried out by persons equipped with self-contained respirators. Those involved in this operation should wear rubber gloves, laboratory coats, and plastic aprons or equivalent protective apparel.

#### **s. Phosgene**

Phosgene is classified as a substance with a high degree of acute toxicity. In humans, the symptoms of overexposure to phosgene are dryness or a burning sensation in the throat, numbness, vomiting, and bronchitis. An airborne concentration of 5 ppm may cause eye irritation and coughing in a few minutes. The substance can cause severe lung injury in 1-2 min at a level of 20 ppm. Exposure to concentrations above 50 ppm is likely to be fatal. Phosgene is extremely toxic to animals via inhalation. Thus, 74% of a group of rats died from exposure to 55-100 ppm for only 10 min. Liquid phosgene is likely to cause severe skin burns and eye irritation. Pulmonary edema, bronchiolitis, and emphysema were found in cats and guinea pigs exposed to 2.5-6.25 ppm of phosgene/day for 2-41 days. A variety of animals exposed to 0.2 or 1.1 ppm for 5 hours per day for 5 days also had pulmonary edema. The threshold limit value (TLV) and the OSHA permissible exposure limit (PEL) for phosgene are 0.1 ppm (0.4 mg/m<sup>3</sup>) as an 8-hour time-weighted average. NIOSH has recommended a limit of 0.2 ppm over any 15-min period.

**Laboratory operations involving phosgene require the use of the general procedures outlined in Part II-C.3.** Work with phosgene should always be carried out within a hood. Unused quantities of phosgene greater than 1 g should be destroyed by reaction with water or dilute alkali. Note that for many applications phosgene can be replaced by the less hazardous reagents diphosgene and triphosgene.

#### **t. Sodium Cyanide (and other cyanide salts)**

Inorganic cyanide salts are classified as substances with a high degree of acute toxicity. Sodium cyanide (NaCN) is among the fastest acting of all known poisons. The lethal oral dose for humans is 200 mg. The symptoms of cyanide overdose include weakness, headache, confusion, and occasionally, nausea and vomiting. Higher doses may be followed by almost instantaneous death. Solutions are irritating to the skin, nose, and eyes, and cyanide is absorbed through the skin. Sodium cyanide is highly toxic to animals via the oral route: LD<sub>50</sub>(rats) = 6.4 mg/kg. It can be corrosive to the skin and the eyes, for it is highly alkaline. Sodium cyanide can also produce toxic symptoms via skin absorption and inhalation. The threshold limit value (TLV-Ceiling) and the OSHA permissible exposure limit (PEL-TWA) for cyanide are both 5 mg/m<sup>3</sup>. These limits include a warning of the potential contribution of skin absorption to the overall exposure. In 1976, NIOSH recommended that the 5-mg/m<sup>3</sup> limit be retained but that its basis be changed from an 8-hour TWA to a 10-min ceiling.

Proper gloves should be worn when handling dry sodium cyanide. Rubber gloves and splash proof goggles should be worn when substantial amounts of sodium cyanide solution are used. Hydrolysis of sodium cyanide (and other cyanide salts) by water or acid generates HCN which is extremely hazardous. Consequently, **cyanide salts should always be handled using the general procedures outlined in Part II-C.3.** All reaction equipment in which cyanides are used or produced should be placed in or over shallow pans so that spills or leaks will be contained. In the event of spills of HCN or cyanide solutions, the contaminated area should be evacuated promptly and immediately determined if anyone had been exposed to cyanide vapors or liquid splash. Consideration should be given to the need for evacuating other parts of the building or notifying other occupants that the spill has occurred. In general, it is usually best not to attempt to dilute or absorb such spills if they occur in well-ventilated areas.

**Detection** – Hydrogen cyanide has a characteristic odor similar to bitter almonds, however, many people cannot smell it in low concentrations, and this method of detection should not be relied on. Vapor-detector tubes sensitive to 1 ppm of HCN are available commercially. The presence of free cyanide ion in aqueous solution may be detected by treating an aliquot of the sample with ferrous sulfate and an excess of sulfuric acid. A precipitate of Prussian blue indicates that free cyanide ion is present.

**Storage** – Sodium cyanide and acids should not be stored or transported together. An open bottle of NaCN can generate HCN in humid air, and HCN may be liberated from spills of sodium cyanide solutions.

**Waste disposal** – Waste solutions containing cyanides should be sealed in clearly marked bottles. Contact the EHS Office to arrange disposal of these containers.

In the event of exposure – Anyone who has been exposed to HCN should be removed from the contaminated atmosphere immediately. Any contaminated clothing should be removed and the affected area deluged with water. Emergency medical attention should be obtained immediately.

## **2.2 Working with Electrical Hazards**

There are inherent dangers involved when using any electrical equipment, and therefore care must be exercised when operating and especially when installing, modifying, and/or repairing any electrical equipment. Electrical shock—the passage of current through the human body—is the major electrical hazard. The diverse types of electrical equipment used in the MRL includes lasers, power supplies, electrophoresis apparatus, electrochemical set ups, X-ray equipment, hot plates and heating mantles. Work involving any of these various classes of equipment can lead to serious injuries if prudent electrical practices are not followed. In order to assure the safe operation of electrical equipment, **all** electrical equipment must be installed and maintained in accordance with the provisions of the National Electric Code (NEC) "National Electric Code (NEC)" of the National Fire Protection Agency.

Modifications and repairs to the receptacle and wiring in the walls are the Facilities Department's responsibility and should not be attempted or carried out by anyone else. Also, it is strongly advised that all work on electrical equipment be carried out by qualified personnel. Consult the NEC handbook section on electrical safety before attempting any **minor** repairs, modifications, or installations of electrical equipment. Also, before carrying out any minor repairs, modifications, or installations of electrical equipment, it is required that the equipment be de-energized and all capacitors safely discharged. Furthermore, this de-energized and/or discharged condition must be verified before proceeding. It is suggested that you consult with MIT's Electrical Services, part of the Facilities Department, before attempting any repairs, modifications, or installations of electrical equipment.

### **Proper Wiring "wiring, electrical"**

The installation, replacement, modification, repair, or rehabilitation of any part of any electrical installation must be in compliance with NEC standards, which specify the proper wiring. For any piece of electrical equipment, there must be a switch disconnect or safety switch on the wall (red emergency stop button) in a convenient and readily accessible location that will disconnect the main power source to the apparatus in the event of an emergency. Only use temporary wiring when absolutely necessary, and it must be replaced with permanent wiring as soon as possible. Temporary wiring must also comply with NEC codes. Extension cords must be used only as temporary wiring for portable equipment. For permanent equipment, permanent wiring should be installed by contacting MIT electrical service, DOF.

### **Grounding "grounding electrical"**

All equipment should be grounded and fused in accordance with NEC. All extension and power cords must have grounding pin.

### **Insulation "insulation, electrical"**

All electrical equipment should be properly insulated. Any power cords that are frayed should be replaced and any exposed hot wires should be insulated to prevent the danger of electrical shock due to accidental contact.

### **Isolation "isolation, electrical"**

All electrical equipment or apparatus that may require frequent attention must be capable of being completely isolated electrically. All power supplies must be enclosed in a manner that makes accidental contact with power circuits impossible. In every experimental setup, an enclosure should be provided to protect against accidental contact with electrical circuits. This applies to temporary arrangements as well.

### **Personal Safety Techniques**

The NEC handbook contains a section on electrical safety that should be read. The following safety procedures should always be followed:

- Before servicing electrical equipment in any way, disconnect and lock out its power source. Then verify that the equipment is de-energized to avoid the danger of electrical shock.
- Test the equipment with a multi-meter to assure that it is grounded before reconnecting electrical equipment to its power source after servicing it.
- Prudent electrical practices also suggest to properly fuse all electrical equipment to protect the user from electrical shock.

### **Work with a partner who is trained in CPR**

When installing, replacing, modifying, repairing, or rehabilitating any part of any electrical installation, it is considered prudent practice to be with a person trained in CPR who can provide CPR if needed in case of an accidental electrical shock.

### **Electrical Hazards and Safety Procedures**

Electricity is in constant use both within and outside the laboratory, but significant physical hazard or death may result from its misuse. With direct current, a man can detect a "tingling" feeling at 1mA and the median "let-go" threshold (the current at which he cannot release the conductor) is 76mA. For 60Hz alternating current, respectively, the values are 0.4mA, when you can detect a "tingling" feeling, and 16mA, is the "let-go" threshold. Women are more sensitive to the effects of electrical current; approximately 2/3 of the current is needed to produce the same effect. (Refer to EHS's "Factors involved in electrical shock" sheet and "Basic-electrical safety practices" sheet). Higher currents produce respiratory inhibition, then ventricular fibrillation, and ultimately cardiac arrest.

Although minute electrical shocks are generally considered annoying rather than harmful, such shocks constitute an ominous warning of the presence of potentially hazardous conditions. The device in question should be disconnected immediately and the cause ascertained by a person competent in such matters. Work on electrical devices should be done only after the power has been shut off and lock out tag-out in such a manner that it cannot be turned on accidentally. Internal current-carrying devices such as capacitors must be discharged refer to section 5.

All "home-made" electrical apparatus should be inspected and approved by someone competent in electrical circuitry before being placed in service. If you feel an electrical "tingle" while working with a piece of laboratory equipment, disconnect it and consult with your supervisor.

In the U.S.:

Three-terminal (115 V AC) electrical wiring should conform to the following color code:

White =	neutral wire
Black =	live/hot wire
Green =	ground wire

Five-terminal (208/230 V AC) electrical wiring should conform to the following color code:

White =	neutral wire
Black =	live/hot wire
Red =	live/hot wire
Blue =	live/hot wire
Green =	Ground wire

Do not short circuit the leads to a battery. Without a fuse, the internal resistance of the battery will cause it to heat and possibly explode. Dangerous arcs or flashes may also be produced.

A ground-fault interrupter does not assure protection against electrocution.

### **50 Volt Limit:**

Untrained people may not work on live equipment greater than fifty (50) volt.

High voltage equipment may be worked on but that equipment must be locked out/tagged out, and verified by a trained person. Always discharge capacitors before beginning.

The following is a list of rules for working with electrical equipment:

- Use only tools and equipment with non-conducting handles when working with electrical devices.
- All current transmitting parts of any electrical devices should be enclosed.
- When checking an operating circuit, keep one hand either in a pocket or behind the back, to avoid an electrical shock.
- Maintain a work space clear of extraneous material, such as books, papers, and clothes.
- Never change wiring with the instrument plugged into a power source and that is not lock out and tag out.
- Never plug leads into a power source unless they are connected to an established circuit.
- Avoid contacting circuits with wet hands or wet materials.
- Wet cells should be placed on a piece of non-conducting material.
- Check circuits for proper grounding with respect to the power source.
- Do not insert another fuse of larger capacity if an instrument keeps blowing fuses. This is a symptom that requires an expert service technician.
- Keep the use of extension cords to a minimum and as short as possible.

- Secure excess power cord out of pathways to prevent tripping.
- Do not use or store highly flammable solvents near electrical equipment.
- Multi-strip outlets (cube taps) should not be used in place of permanently installed receptacles.
- Keep access to electrical panels and disconnect switches clear and unobstructed (three feet of floor space).
- Make certain that all electrical equipment (lamps also) is properly grounded.
- Be alert and aware of the dangers inherent in high voltage equipment.
- In the event of a small electrical fire or accident:
  - Turn off the power source and unplug the equipment if you can do so safely.
  - Dial 100 and/or activate fire alarm pull station.
  - Do not turn on the circuit until the cause of the fire has been verified and the fault corrected.
  - Report the fire to the EHS Office (ext. 2-3477) (this is not necessary since dialing 100 and pulling the alarm will inform us)

### **2.3 Working with Lasers**

If you work with lasers, you must read the MIT Laser Safety Manual available from the Environmental Health and Safety Team (EHS), N52-496. The MIT Laser Safety Manual is also available from MRL EHS Coordinator

### **2.4 Working with Radiation and Radioactive Materials**

All work with radioactive materials and equipment that produces radiation (shorter than UV wavelength) is regulated by the EHS Office (N52-496, 452-3477). The responsibilities of the EHS Office include:

- Registration and instruction of radiation workers.
- Personnel monitoring of internal and external radiation exposure.
- Radioisotope laboratory inspections and radiation surveys.
- Radioactive waste collection and disposal.
- Environmental monitoring.
- Leak-testing of sealed radioactive sources.
- Monitoring of incoming and outgoing shipments of radioactive material.
- Supervision of radiation emergencies and special contamination operations.
- Operation of an MIT vehicle for transportation of radioactive material.
- Maintenance of radiation protection records.

In addition, the EHS Office staff is available for (a) consultation on laboratory design, shielding, and other radiation exposure control methods, and (b) presentation of lectures and training exercises on radiation protection techniques.

**Procedures for Working with Radiation "radiation, procedures for work with"**



All work with radioactive materials and radiation-producing equipment must be registered with EHS. Specific procedures as well as application and registration forms may be found in the booklet, *Required Procedures for Radiation Protection*, available from the EHS Office.

### **Work with Radioactive Materials**

- Application for the possession and use of radioactive material must be made in writing to the EHS Office by the Laboratory Supervisor using Form RP-01.
- All personnel using radioactive materials must register with EHS and participate in a training seminar held by that office. Researchers are also required to pass an exam on the material presented in the training seminar. It is the Laboratory Supervisor's responsibility to ensure that only registered researchers use radioactive material.
- The Laboratory Supervisor must maintain an up-to-date inventory of all radioactive materials in use, where they are used, and who is authorized to use them.
- Handling radioactive materials must be done in accordance with instructions received by EHS.
- Radioactive materials must be maintained under lock and key at all times in accord with the requirements of the EHS Office.

### **Work with Radiation-Producing Equipment**

This section applies to the use of x-ray diffraction equipment "x-ray diffraction equipment", fluorescence analysis equipment "fluorescence analysis equipment", and any other equipment that produces ionizing radiation. Specific procedures and registration forms for using this equipment can be found in the booklet *Analytical X-ray Equipment Safety Program* available from the EHS.

- Laboratory supervisors must fill out an RP-81 form describing the proposed use of any radiation equipment. Approval from the EHS Office must be obtained before the equipment is operated.
- All personnel using the equipment must register in writing with EHS and receive specific training from them for the equipment used. It is the Laboratory Supervisor's responsibility to ensure that only authorized, properly trained personnel use the equipment.
- Use of radiation-producing equipment must be carried out in accordance with the instructions received by EHS.

## **2.5 Working with Cryogenics**

### **Cryogenic hazards**

1. Cold burns
2. Pressurization
3. Oxygen enrichment and condensation
4. Damage to equipment
5. Oxygen deficiency and Asphyxiation
6. Conclusions

The normal cryogenic hazards in the laboratory are caused by liquid nitrogen (boiling point 77K) and liquid helium (boiling point 4K). These colorless liquids are used in food freezing and chilling, metal fabrication processes, biological sample preservation, vacuum pumping systems, cooling infrared detectors, cooling samples in electron microscopes, cryostats for low temperature research and superconducting magnet systems, (e.g. magnetic resonance imaging equipment).

The liquids are transported in vacuum insulated containers called dewars, which can then be wheeled (slowly and carefully please) to the point of use. Liquid nitrogen is transferred to equipment by either filling a small dewar and pouring the liquid into the equipment or by pressurizing the dewar and passing the liquid through a tube. Liquid helium is always transferred via a vacuum insulated tube to minimize loss through boil-off as well as to avoid contamination by gas condensing from the air. In some places the boil-off helium gas is collected via pipes, compressed and returned to a helium liquefaction plant.

### Cold burns

Cryogenic liquids or cold gas produces damage similar to heat burns. Skin may stick to cold surfaces, the cold reducing the pain while damage is occurring but not when the flesh warms up!

Use insulating gloves when handling cold objects and liquids. Be very aware of the possibility of liquid soaking through gloves or other clothing - if this happens, remove affected clothing immediately. The worst burns occur where the liquid soaks into cloths and is held close to the skin, liquid poured onto skin will do little damage if it is allowed to roll off quickly. Wear trousers outside boots, and do not wear sandals (liquid soaks into socks).

Wear goggles or a face shield when liquids may erupt towards you e.g. pressurized delivery of liquid nitrogen. Avoid sudden events of this nature by opening valves slowly and carefully.

If you are slightly burnt hold the affected area under running cold water, this will reduce the damage and relieve the pain. You should seek medical aid to dress the burn and should report the incident to the departmental safety officer and MRL.

### Pressurization

1 liter of liquid will turn into 700 liters of gas that can cause a large pressure build up. Always think carefully about how the gas escapes from the liquid container and do not allow this route to become blocked. Pressurization followed by a possible explosion may occur because:

A. The wrong valve has been closed.

B. A catastrophic loss of vacuum from the cryostat has occurred (the vacuum acts so as to insulate the liquid gases from each other and the outside world). This sort of event may occur if a dewar is tipped over onto its side causing the tubes supporting the inner chamber (containing the liquid) to break.

C. Water vapor, condensing from the air and forming ice in the outlet tube, prevents boil off gas from escaping. This problem occurs particularly in cryostats that contain both liquid nitrogen and helium. When the cryostat has just been filled with liquid helium, the nitrogen will boil off very slowly and ice forms in the tubes to the nitrogen reservoir. The solution is to use a one way 'Bunsen' valve which is easily constructed from a piece of rubber tubing with a slit in it and a bung.

D. A superconducting magnet 'quenches' i.e. changes spontaneously from a superconducting state to a normal state. This releases large amounts of energy stored in the magnetic field, and evaporates all the liquid helium in the cryostat in a few seconds.

Any sudden evaporation of liquid gases in a confined space may also lead to asphyxiation (c.f. section 5).

## Oxygen enrichment and condensation

When using a liquid nitrogen trap, charge the trap only after the system is pumped down. Otherwise considerable amounts of liquid oxygen could condense, thus creating a major hazard. This may lead to an explosion or fire, in particular oil and grease may ignite spontaneously in the presence of high oxygen concentrations.

### Damage to equipment -

Damage may occur to equipment due to cryogenic liquids, causing danger.

- A. Condensation of water around electrical cables may result in an electric shock hazard.
- B. The freezing of electrical cables may break the insulation and result in shock hazard.
- C. The formation of ice around inlets and outlets may apply stresses to equipment resulting in damage.
- D. Spilled liquid nitrogen will crack floor tiles. This may create problems.
- E. Rubber tubing through which liquid nitrogen is being transferred may suddenly crack, spraying liquid everywhere.
- F. Liquid nitrogen should never be poured down a sink, this will crack waste pipes causing potentially dangerous leaks.

## OXYGEN DEFICIENCY AND ASPHYXIATION

The use of liquid gases, particularly in confined and unventilated spaces may lead to a change in the proportion of oxygen in the atmosphere. A reduction from the normal value in air (18%) to below 14% may start to affect individuals, a reduction below 6% will cause fainting and brain damage. The onset of oxygen deficiency problems is often not apparent to the individual affected.

In particular sudden events such as a superconducting magnet quench where large quantities of liquid helium are suddenly released into the atmosphere, the air may be displaced (the helium will occupy the upper part of the room). In this case it is best to leave the room as quickly as can be achieved with safety.

### Conclusions

There are many potential dangerous situations that can develop with liquid cryogenes. To avoid this happening make sure that you know how to operate equipment properly, always think carefully about the consequences of your actions, act with patience and make sure that when you leave equipment it is in a safe state.

## 2.6 Working with Biological Hazards

Biological hazards are agents of biological origin that present a possible threat to the environment or to the health of laboratory personnel. Such materials include, but are not limited to, cells, viruses, spent media used for their propagation, animal or human tissues, genetic material of pathogenic organisms and any nucleic acid that is categorized as "recombinant DNA."

This document provides an overview of the procedures to be used while working with biological hazards in the Center. It is not meant to be a detailed safety manual because such documents are available through the **EHS Office** and other units within the Institute. Rather, the following is a resource identification guide to the more comprehensive safety documents published by groups within MIT charged with protection against exposure to specific biohazardous agents.

The following offices provide services relating to the physical methods of biohazard control at MIT:

**Environmental, Health and Safety Team (EHS Office)      452-3477**

**Division of Comparative Medicine (DCM)                      253-1757**

In the discussion below, reference will be made to six documents that are available to every laboratory through the EHS Office (documents 1 and 2), which administrates the first three offices listed above, the MIT Division of Comparative Medicine (DCM; documents 3-5), and the Whitaker College Division of Toxicology (document 6).

**Resource documents:**

1. Guidelines for Biological Research at MIT
2. Required Procedures for Radiation Protection
3. Institutional Guidelines for the Care and Use of Laboratory Animals
4. Instruction Manual for Laboratory Animal Care and Use
5. Essentials for Animal Research
6. Division of Toxicology Safety Manual

Numerical documentation within the text refers to the numbers above.

**Registration of Personnel Working with Biohazardous Materials**

It is the responsibility of the Principal Investigator (usually a faculty member) to register with EHS, and if necessary, DCM prior to working with biohazardous materials. The specific registration procedures typically require a written application. Since the procedures vary greatly with the nature of the work being conducted, it is best to contact EHS or DCM directly to obtain the appropriate registration forms. For some proposed work, detailed review by an Institute committee (Committee on Assessment of Biohazards, Committee on Animal Care, etc.) must precede formal authorization. Registration procedures for projects involving recombinant DNA research and other work formally defined as "biohazardous" are given in resource document 1 [chapter entitled "Registration"]. Procedures for work with animals where a risk is posed to the investigator are in document 3 [section V, "Personal Health," pp 1-40].

Examples of specific procedures involving work with biological hazards and the corresponding office within MIT through which authorization must be sought are given in the next section.

**Biohazard Classification**

**1. Projects that must be registered with the Committee on Assessment of Biohazards.**

- **All** recombinant DNA projects, including studies considered *exempt* under the NIH guidelines.
- **All** studies with human source material (e.g., blood, serum, cells, etc.) Such materials pose hazards from potentially pathogenic agents, hepatitis virus, human T-cell leukemia virus (HTLV), and human immuno-deficiency virus (HIV). Personnel working with potentially infectious material must attend an OSHA-mandated training session (see section D).
- **All** work with micro-organisms.

The contact office within MIT is the EHS Office at 452-3477.

**2. Projects that must be registered with the Committee on Animal Care.**

All projects involving live animals require the authorization of the Committee on Animal Care. An example of a project needing this authorization would be one in which pathogenic viruses are to be isolated from the tissues of experimental animals. This project would require the authorization of the Committee on Animal Care (contact the DCM), as well as the approval of the EHS Office.

- **Projects that must be registered with the Committee on the Use of Humans as Experimental Subjects.**

An example of such a study would be one in which enzymes are isolated from a human tissue, such as placenta. Owing to the significant incidence of transmissible diseases in the population, all human tissues should be considered as having infectious potential. Contact Dr. Leigh Finn's office (3-6787).

#### **4. Projects that must be registered with the EHS Office.**

Note that **all** projects involving radioactive substances require the authorization of the EHS Office, regardless of whether or not a biohazard is generated. There are many experiments in which a radioactive biohazardous agent is generated (e.g., a radioactive AIDS virus or a pathogenic bacterial cell). The use **and disposal** of these agents requires special procedures, and investigators are required to contact the RPO for guidelines prior starting the experiment [see resource document 2 (p. 20) and contact the RPO 3-2180].

#### **Procedures for Personnel Working With Potentially Pathogenic Agents**

"Bloodborne Pathogens" refers to microorganisms potentially present in human blood that can cause human diseases. Examples are Hepatitis B Virus (HBV) and HIV. OSHA defines potentially infectious materials containing such pathogens as: including human blood components, products made from human blood, various body fluids, and HIV or HBV containing cell or tissue cultures and media. Use of human derived cell lines and tissue culture is also included.

All personnel carrying out studies that involve possible occupational exposure to bloodborne pathogens must, before beginning any work, view a videotape presentation put out by the Biosafety Program entitled "*Basic Bloodborne Pathogen Training*" and review MRL's Exposure Control Plan. All members of groups involved in such studies must participate annually in a group (OSHA-mandated) training program on bloodborne pathogens held by the EHS Office that is specifically designed around the individual laboratory's work and needs. In addition, it is strongly recommended that all such personnel working with human blood, body fluids, and tissues receive a recombinant DNA vaccine which is available for HBV. This vaccine is offered free of charge by EHS and arrangements may be made through the Medical Department/Jackie Sherry (253-1770).

#### **Containment of Biohazardous Material**

Containment is the minimization of risk to personnel and the environment from biohazardous material. There are two levels of containment.

**Primary containment** includes safety techniques and devices used to separate personnel physically from the biohazard. Specific examples include the use of protective laboratory clothing, the use of aseptic technique in a manner that avoids environmental spread of the pathogenic agent in use, and the use of safety cabinets to minimize the spread of aerosols.

**Secondary containment** pertains to laboratory design and operational features used to protect the environment by physically containing the biohazardous agent within the laboratory. Specific examples of secondary containment considerations are the use of non-porous surfaces for benchtops and floors in the laboratory, the type of door used to separate the laboratory from public areas, the type of ventilation system in use, and the location of autoclaves proximal to the site of biohazard research. The key resource documents dealing with containment are the Division of Toxicology [document 6, section entitled "Biohazards"] and the recombinant DNA Research Guidelines [document 1, section on "Containment"].

The required level of primary or secondary containment is in direct relation to the perceived risk of the biohazardous agent being used. Four levels of physical confinement (**BIOSAFETY-LEVELS**, BL-1 through BL-4) are defined by local, national, or Institute codes [see resource documents 1 (section on "Containment") and 6 (section on "Biohazards")] and are as follows:

**BL-1.** Minimal or no hazard to personnel or the environment. Most work at MIT falls into this category. Note that all recombinant DNA research is at least BL-1.

**BL-2.** Potentially pathogenic organisms are used; this includes plant or animal pathogens. Three examples are polio, hepatitis, and human immuno-deficiency (AIDS) viruses.

**BL-2+.** Work with agents known to cause serious disease. BL-3 protocols are followed but in a designated normal laboratory with closed doors. All equipment for experimental work is located in that laboratory.

**BL-3.** Threat of serious or lethal disease. Typical examples include work with high titers of HIV. A specialized laboratory with key-card entry is mandated.

**BL-4.** Extremely hazardous infectious agents. BL-4 work is neither authorized nor planned at MIT owing in part to local codes, and will not be considered further here.

### **Storage, Decontamination and Disposal of Biohazardous Material**

Specific procedures for storage, decontamination and disposal of biohazardous agents have been formulated by the EHS Office. There are two key documents pertaining to this section—document 1 [sections on "Containment", "Decontamination", and "Waste Disposal"] and document 6 [section on "Biohazard Waste"].

#### **1. Storage and growth of living biohazardous agents**

**BIOHAZARD** labels, available from the EHS Office (452-3477), must be affixed to any equipment used to store (e.g., refrigerators), grow (e.g., incubators), or manipulate (e.g., centrifuges) biohazardous agents.

#### **2. Storage of biohazardous waste**

- **BL-1 and BL-2 Solid waste** - Solid waste containers shall consist of a terminal (nonreusable) autoclave bag in a labeled, covered, leak-proof biohazard marked container located in an appropriately marked and confined area.
- **BL-1 and BL-2 Liquid waste** - BL-1 waste may be stored in a covered container in the laboratory prior to decontamination. BL-2 waste, by contrast, must be chemically decontaminated immediately after its generation (Note—this waste must be subsequently autoclaved). (this is not necessary but if you leave it in you must adhere to it)
- **Physically hazardous waste** - Physically hazardous waste (e.g., sharps) from BL-1 and BL-2 designated labs must be collected in puncture resistant containers provided by a vendor. Arrangements should be made through EHS (ext. 2-3477) to provide regularly scheduled pickup and replacement service for these containers.

#### **3. Treatment of biohazardous waste**

Organisms may be rendered innocuous by chemical disinfection (e.g., by bleach or Wescodyne) or wet heat sterilization (autoclaving). Detailed procedures customized to specific experimental protocols are in resource document 1 [section on decontamination].

There has recently been a new state regulation [105 CMR 480.000] requiring MIT and other institutions to document the storage and disposal of medical and biological waste. It is now necessary for all autoclave facilities to record the following information for each autoclave run: the time and temperature setting of the autoclave, the volume and type of waste generated, and the name of the person responsible for the waste [see "Biohazard Waste" section of resource document 6]. To verify the sterilization effectiveness of the autoclave, biological spore tests must be performed periodically. Details of this test are in the aforementioned section of document 6 and in the section on "Autoclave Validation" in reference 1.

As part of the logging process, a tag is affixed to the biohazardous waste. This tag has on it the specific identification number of the Principal Investigator (the faculty member in charge of the research). Note that this tag stays with the bag permanently. Tags are available from the EHS Office.

#### **4. Disposal of non-infectious biological waste**

- **Solid waste** - There are three types of decontaminated solid waste: autoclaved solids, chemically treated solids, or physically hazardous materials (e.g., sharps). Once these materials have been rendered noninfectious, all **BIOHAZARD** signs or symbols must be removed from sight. The formerly biohazardous waste is then removed by the custodian. Note that the usual rules regarding disposal of sharp objects must be followed in order to protect the custodian and others who may subsequently handle the waste materials.
- **Liquid waste** - Once liquid waste such as spent bacteriological media has been rendered non-infectious by autoclaving or chemical treatment, it can be disposed of by washing down the sink.

#### **5. Treatment and disposal of radioactive biohazardous waste.**

Wherever possible, radioactive biohazardous waste should be treated chemically to render it non-infectious. The EHS Office should then dispose of it as radioactive waste. It is noted that such disposal procedures must be approved by the EHS prior to doing the experiment [see resource document 2, p. 20].

### **3. LAB SPECIFIC SOP TEMPLATE INSTRUCTIONS**

#### **3.1. Title, Authors, Reviewers, Date and Hazard Type**

Complete the blanks shown in this section. The revision date should indicate when the most recent modifications were made to this procedure. The title of the procedure should indicate the specific chemical, task or experiment for which it was written. Note that each procedure, and its subsequent revisions, should be reviewed by the PI, and the Chemical Hygiene Officer. The EHS Office can review the SOP as well. The most appropriate box to indicate hazard type covered by the Laboratory Specific SOP should be checked.

#### **3.2. Scope and Applicability**

Complete boxes. Include a general description of what activities are covered under this procedure. List any specific examples of when the procedure must be implemented or any exemptions when the procedure is not required. If authorization for this procedure is limited to designated staff, that fact should be noted in this section. The brief description of the operation or experiment should be used to summarize the basic safety concerns or hazards and critical controls.

#### **3.3. Chemical Hazards**

Complete the hazard description table for each of the principal materials utilized in this procedure. Safety Data Sheets, when available, should be obtained and attached to the procedures template. Many operations can result in secondary materials or hazardous by-products. A discussion of these materials should be included in this section if they represent a significant, but different hazard than the other materials, or if the hazard is unknown. Information about the SDS location for chemicals should be noted, or the SDS (s) could be attached to the SOP.

### **3.4. Step by Step Hazard Summary**

In most cases, the hazard is not just about the chemical(s) being used, but how they are being used. In some cases the hazards may be related to the equipment being used for a step, or to the nature of the process involving materials used. This section is appropriate for a procedure involving several steps or tasks, as do most experiments, highlighting concerns at critical points in the process. List the step, hazards associated with the step, and the controls to contain the hazard. Example SOPs are provided at: <http://ehs.mit.edu/site/content/chemical-hygiene-program>

### **3.5. Personal Protective Equipment (PPE)**

Conduct a comprehensive Personal Protective Equipment (PPE) evaluation for the referenced materials or operation. The determination should include both the type of protective equipment or clothing materials. The results from this evaluation should be identified by completing the PPE and Clothing tables, but could also be included in the step by step process in section 2.4 above.

This section can be used to provide more details regarding PPE to be used, such as gloves, clothing, eye protection, etc. For guidance on PPE assessment, go to: <https://ehs.mit.edu/workplace-safety-program/personal-protective-equipment/>.

### **3.6. Special Precautions**

Provide general information on specific training requirements for the procedure, any medical surveillance requirements, or other precautions that might be warranted.

### **3.7. Special Emergency Procedures**

Generic information related to emergency response activities is already addressed in Part II. Section 3. of the Chemical Hygiene Plan. List any additional or specific equipment, supplies or procedures that are unique to the process or operation in this SOP.

## **4. STANDARD OPERATING PROCEDURES**

This section contains the Lab Specific SOPs developed for specific laboratories, experiments or operations.

[Note: Insert your custom SOPs to this section here, if applicable, based on the template that follows in 4.a Appendix IIIA]





**Describe how and where SDS information for above chemicals is maintained in the lab (notebook or on computer or attached to this SOP)**

**STEP BY STEP HAZARD ANALYSIS**

Enumerate the steps to be followed in performing the procedure and the required precautions to avoid harm. The steps should be detailed and should include prohibited activities and cautionary statements, where applicable. Include in procedure waste management requirements.

<b>Task</b>	<b>Hazards</b>	<b>Precautions</b>

**PERSONAL PROTECTIVE EQUIPMENT (PPE)**

**Special PPE** required is noted below. **Note:** Standard PPE, listed in Part II of the Department CHP should always be worn in the lab. The section below is for additional PPE required due to the unusual nature of materials involved. If no additional PPE is needed, this section can be deleted.

<input type="checkbox"/>	Goggles	<input type="checkbox"/>	Faceshield	<input type="checkbox"/>	Safety Glasses
<input type="checkbox"/>	Protective Clothing, Special lab coat, chemical resistant apron, etc. (list type)				
<input type="checkbox"/>	Other (list item or items)				
<input type="checkbox"/>	Gloves (thickness, length, and whether disposable or reusable should also be considered in gloves selected.)				
<input type="checkbox"/>	<input type="checkbox"/>	Butyl	<input type="checkbox"/>	<input type="checkbox"/>	Neoprene
<input type="checkbox"/>	<input type="checkbox"/>	Nitrile – double glove	<input type="checkbox"/>	<input type="checkbox"/>	Silver shield or 4H
<input type="checkbox"/>	<input type="checkbox"/>	PVC	<input type="checkbox"/>	<input type="checkbox"/>	Kevlar
<input type="checkbox"/>	<input type="checkbox"/>	Latex	<input type="checkbox"/>	<input type="checkbox"/>	Other (list)
<input type="checkbox"/>	Respirator (If checked, contact EHS Office for additional assistance, unless already in program)				

**SPECIAL PRECAUTIONS**

<input type="checkbox"/>	Training:
<input type="checkbox"/>	Medical Surveillance:
<input type="checkbox"/>	Temperature/Pressure Sensitive:
<input type="checkbox"/>	Primary Containment (i.e. BSC, Fume Hood, Glove Box):
<input type="checkbox"/>	Other:

**SPECIAL EMERGENCY PROCEDURES**

This section is for any emergency procedures different from standard responses, or for additional emergency information due to the nature of materials or task.

<input type="checkbox"/>	Fire/Explosion:	
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Chemical Spill:	
Personal exposure or other medical emergency:	

I give permission for EHS to post this on ehs.mit.edu accessible only to the MIT Community

Definitions: BSC: Biosafety Cabinet  
CHP: Chemical Hygiene Plan  
CHO: Chemical Hygiene Officer  
EHS: Environment, Health and Safety  
PPE: Personal Protective Equipment  
SDS: Safety Data Sheet  
SOP: Standard Operating Procedure

## PART IV. Additional Administrative Provisions

### 1. INTEGRATION WITH MIT EHS MANAGEMENT SYSTEM

MIT has designed and implemented a comprehensive and integrated *Environment, Health and Safety Management System* (EHS-MS). This management system provides better institutional accountability for achieving and maintaining compliance with federal, state, and local environment, health and safety regulations in MIT's departments, laboratories, and centers, while simultaneously retaining the independence of research and teaching. The EHS-MS also seeks to create a more sustainable campus by encouraging the incorporation of positive initiatives into activities, such as reducing wastes and toxics, preventing pollution, and conserving and reusing resources. One of the defining features of MIT's EHS-MS is the integration of regulatory compliance with positive initiatives and educational programs in a decentralized academic research setting.

This Chemical Hygiene Plan is an integral component of the EHS-MS. It is an administrative tool that provides for the establishment of safe and sound workplace practices in the laboratory, and ensures the Institute's regulatory compliance with the OSHA *Laboratory Standard*. The Chemical Hygiene Plan incorporates and advances core components of the EHS-MS, such as clarifying roles and responsibilities, outlining training requirements, identifying chemical risks, and documenting safe operating procedures to mitigate those risks. For more information on the EHS Management System, please visit <https://ehs.mit.edu/about/ehs-management-system/>.

### 2. SECURITY, PRIOR APPROVALS, INVENTORIES AND PROCUREMENT

#### 2.1. Chemical Inventory and Security

To minimize the theft and improper use of hazardous chemicals including toxic and corrosive substances the following actions should be taken:

1. The MIT Committee on Toxic Chemicals has instituted a requirement to maintain an inventory of hazardous chemicals. Hazardous chemicals include chemicals for which there is statistically significant evidence of health effects following exposure as well as flammable and explosive substances. Although inventories can be kept using any type of electronic or non-electronic method, the use of MIT's centrally provided chemical inventory platform which is supported by EHS is strongly recommended. For more information please visit <https://ehs.mit.edu/chemical-safety-program/chemical-inventory/>, or by calling 2-3477. Your lab's inventory should be used to:

- Manage the chemical purchases to reduce or completely eliminate unnecessary purchases. Prior to purchasing new chemicals, review your lab's current chemical inventory/search the shared inventory in the centralized system. When purchasing new chemicals, purchase minimum quantities necessary for your work. Less over-purchasing will lead to less chemical waste.
- Provide a list of applicable chemicals to EHS when requested to meet regulatory reporting requirements, such as MIT's annual SARA Inventory Reporting requirement see Part IV section 9.

In addition please indicate whether a chemical substance is an engineered nanomaterial, having at least one dimension in the nano range (1 to 100 nm), by adding the designation, "nano" to the name. This includes engineered nanoparticles, wires, tubes, and other nano structures.

2. Access to all hazardous chemicals, including toxic and corrosive substances, should be restricted at all times. Specifically, good practice would dictate that these materials be stored in laboratories or storerooms that are kept locked at all times when laboratory personnel are not present. Also, there are a few select highly toxic chemicals, requiring prior approval for purchase see #4, which additional

precautions are required such as keeping the materials under a second layer of security e.g. locked storage or gas cabinet, drawer, storeroom or other security measures. These chemicals are hydrogen cyanide, arsenic trioxide, chlorine, nitrous oxide, phosgene, potassium cyanide (analytical reagent and purified), sodium arsenate (analytical reagent), sodium cyanide (analytical reagent) see <http://vpf.mit.edu/instructions-for-purchasing-hazardous-and-dangerous-items> Contact the EHS Office to determine the appropriate controls. Contact the Campus Safety Working Group (CSWG) to request security cameras to be installed in your DLC.

3. In the case of highly toxic chemicals, the requisition must be signed by a member of the Institute community with the title Department Head, Laboratory Director, Professor, M.D., or Pharmacist, see <https://vpf.mit.edu/instructions-for-purchasing-hazardous-and-dangerous-items>. These are hydrogen cyanide, arsenic trioxide, chlorine, nitrous oxide, phosgene, potassium cyanide (analytical reagent and purified), sodium arsenate (analytical reagent), and sodium cyanide (analytical reagent). Other unusually toxic or hazardous materials to consider for this level of security include needles and syringes that could be used to administer drugs should be kept secure at all times either in a locked laboratory or a locked laboratory cabinet. They should only be utilized in a laboratory space that provides a barrier to access.

4. Areas where biological agents and radioactive material are stored should be kept secure when not in use.

5. Restrict access to the laboratory to authorized personnel only and become familiar with these people

6. Ship chemicals by following requirements in Part II section 9 to ensure safety and security.

## 2.2. Department, Laboratory, or Center-Based Prior Approvals

Researchers must obtain prior approval from the DLC EHS Coordinator and or the DLC EHS Committee before purchasing any of the 41 chemicals (see Part IV Appendix 10.1) with low threshold reporting quantities from the Department of Homeland Security (DHS) larger list of chemicals of interest (COI). EHS Coordinators will inform the EHS Office when a chemical from the list is purchased (though no prior approval from the central EHS office is required).

It is recommended that Departments, Laboratories, or Centers (DLCs) institute a program for requiring prior approvals before work with certain hazardous materials can commence. A suggested framework is provided in the *CHP Preparer's Guide*, located at [http://ehs.mit.edu/site/sites/default/files/CHP\\_Preparers\\_Guide.pdf](http://ehs.mit.edu/site/sites/default/files/CHP_Preparers_Guide.pdf). Details of the program should be included here. If no program is implemented, this Section 2.1 should be deleted.]

## 2.3. MIT-Wide Signature Control Program for the Purchase of Certain Hazardous Materials

The MIT Procurement Department through its *Purchasing Policies and Procedures* has established Institute-wide restrictions on the purchase of certain hazardous materials. These materials require pre-approval by authorized MIT agents prior to purchase. These materials include:

- |   |   |
|---|---|
| <input type="checkbox"/> Radioactive Materials                | <input type="checkbox"/> Nitrous Oxide Gas              |
| <input type="checkbox"/> Controlled Substances, such as drugs | <input type="checkbox"/> Explosives                     |
| <input type="checkbox"/> Hypodermic Needles and Syringes      | <input type="checkbox"/> Liquid Petroleum Gases         |
| <input type="checkbox"/> Ethyl Alcohol                        | <input type="checkbox"/> Certain Biological Materials   |
| <input type="checkbox"/> Certain Poisons                      | <input type="checkbox"/> Certain Highly Toxic Chemicals |

Detailed information on the purchase of these materials can be found on the Procurement Department's website at

[http://vpf.mit.edu/site/procurement/policies\\_procedures/policies\\_and\\_procedure\\_manual/4\\_0\\_requisitions](http://vpf.mit.edu/site/procurement/policies_procedures/policies_and_procedure_manual/4_0_requisitions)

#### 2.4. Purchase of Large Chemical Quantities

In most cases, MIT discourages the practice of bulk ordering of chemicals that reduces the chemical cost per unit volume. Although bulk orders may save individual Departments, Laboratories, and Centers (DLCs) money in the short-term, in the long run, the cost of disposal of unused chemicals can far outweigh any savings from the bulk order. However, if it can be demonstrated that the bulk purchase of a chemical for an on-going laboratory process can simultaneously reduce disposal costs and not increase risks to environment, health and safety, the EHS Office may support some degree of bulk purchasing. Contact the EHS Office to discuss particular situations if you are considering a bulk purchase.

The following points should be addressed to determine the proper volume of any chemical to order. Consider the following when placing an order:

- ❑ Investigate if there is a less hazardous substitute that can be used to achieve the same results. This could reduce the hazards involved in the process as well as the waste disposal costs.
- ❑ Order only the amount likely to be used for its intended purpose within the specified shelf life of the material and within the planned timeframe of the procedure. This can minimize chemical waste if processes or research changes and previously purchased chemicals are no longer needed. Although many chemicals can be safely stored over long periods of time, decomposition can result in explosions, ruptured containers and the formation of hazardous by-products.
- ❑ Evaluate the chemical properties that may preclude long-term storage before the chemical quantity to be ordered is decided.
- ❑ Order only the quantity that will fit into the appropriate storage area(s). Storing excess chemicals in a fume hood or outside adequate storage facilities will create other hazards.
- ❑ Request that the chemical vendor package the material in smaller containers on large orders and request that stock be delivered on an as needed basis. This is particularly useful when one lot or a special blend is required.
- ❑ Consult laboratory chemical inventory lists, if available, before ordering additional stock. If the decision is made to order new stock because of concerns about quality of existing stock, please properly dispose of existing stock of questionable quality as soon as possible.
- ❑ Manage the stock so that the oldest materials are used first.
- ❑ Refer to the EHS Office *Flammable Liquids SOP* when applicable. EHS Office SOPs are available at <https://ehs.mit.edu/sops/> (certificate login is required).
- ❑ Refer to the EHS Office *Hazardous Waste Management SOP* when applicable. EHS Office SOPs are available at [https://ehs.mit.edu/sops](https://ehs.mit.edu/sops/) (certificate login is required).

If you need assistance in making a determination on the most appropriate quantity of chemical to purchase, please contact the EHS Office at 617-452-3477.

#### 2.5. Purchase of Non-Returnable Gas Cylinders

The purchase of non-returnable gas cylinders should be avoided. All gas cylinders should be returned to the supplying vendor when their use is completed. All non-returnable cylinders will have to be disposed of as hazardous waste, and the cost of doing so will be charged to the Department, Laboratory, or Center.

“Lecture bottles” are often considered non-returnable by the vendor. However, MIT has an agreement with their preferred chemical vendor, Airgas, to take back non-returnable gas cylinders, including “lecture bottles” that were purchased through them. Contact Airgas Gas on-campus directly at 617-253-4761 (3-4761 from an MIT telephone) for more information.

#### 2.6. Purchase of Select Toxins

Certain biological toxins are governed by special regulations that require strict controls if threshold amounts are exceeded. Researchers working with regulated toxins must submit paper requisitions to the EHS Office Biosafety Program. More details are provided at <https://ehs.mit.edu/biological-program/select-agent-toxins/>

### 3. MEDICAL EVALUATION, EXAMINATION, SURVEILLANCE and FIRST AID KITS

#### 3.1. Medical Evaluation

Employees or students who wish to discuss occupationally-related medical issues with the MIT Medical Department may do so. During this medical evaluation, the clinician will determine if a medical examination is necessary. Medical evaluations and examinations may be arranged by contacting the Medical Department, Occupational Medicine Service at 617-253-8552.

#### **When a Medical Evaluation May be Necessary**

Any employee who exhibits adverse health effects from a chemical or hazardous material exposure as a result of MIT-related research or work should report to the Medical Department immediately for a medical evaluation.

Employees or students who work with hazardous materials are entitled to a medical evaluation when any of the following conditions occur:

- The individual(s) develops signs/symptoms associated with hazardous chemicals to which they were exposed;
- Exposure monitoring results are routinely above action level or PEL (permissible exposure limit) for a substance for which there are monitoring/medical surveillance requirements; or
- A spill, leak, explosion or other incident creates a likelihood of exposure.

#### **Information to Provide to the Clinician**

At the time of the medical evaluation, the following information shall be provided to the clinician:

- Identity of the hazardous chemicals to which the individual may have been exposed;
- A description of the conditions under which the exposure occurred;
- A description of the signs and symptoms of exposure, if any; and
- A copy of the chemical information sheet (MSDS, or Material Safety Data Sheet) shall be provided.

#### **Clinician's Written Opinion**

The MIT Medical Department and the Industrial Hygiene Program within the Environment, Health and Safety Office have a collaborative relationship in dealing with chemical and other work-related exposures that may result in the need for medical care. This collaborative relationship includes protecting patient information while ensuring that supervisors receive the information necessary to ensure that an individual's return to work following medical treatment for a work-related exposure does not compromise the patient's health.

All patient medical information is protected by law and is considered strictly confidential. A patient, however, is entitled to view his/her medical record. When a work-related exposure has occurred that results in medical examination and/or treatment, the Medical Department will notify the supervisor of the incident, along with any recommended restrictions on work activity.

#### **Additional Steps to be Taken**

MIT requires the *Supervisor's Report of Occupational Injury and Illness* to be completed within 24 hours, when a spill or other accident triggers a medical evaluation or examination. The reporting form can be accessed at <https://ehs.mit.edu/workplace-safety-program/occupational-injury-or-illness-reporting/>. An MIT personal certificate is required to access this document.

The MIT EHS Office has developed a standard operating procedure (SOP), "Reporting Work-Related Injuries and Illnesses of OSHA-Covered Personnel" to assist Departments, Laboratories, or Centers (DLCs) in this type of reporting, which OSHA requires. The SOP may be found at <https://ehs.mit.edu/sops/> (certificate login is required).

### 3.2. Medical Surveillance

Medical surveillance is the process of using medical exams and/or biological monitoring to determine potential changes in health as a result of a hazardous chemical or other exposure. Certain OSHA standards require a clinician evaluation as part of medical surveillance. Medical surveillance is required when initial monitoring reveals exposure levels that exceed levels (called "action levels") allowed under OSHA standards. MIT Medical Department provides medical surveillance services. If you expect that your work will involve a hazardous exposure that may not be sufficiently addressed through engineering or administrative controls, a baseline exam may be advised before beginning work. The baseline exam is compared against follow up exams to determine any changes in health that may have resulted from exposure to the hazard. In addition, medical surveillance is offered to employees or students who are routinely exposed to certain hazards. Examples of hazards that are monitored through the medical surveillance program include:

- Asbestos
- Beryllium
- Noise (Hearing Loss)
- Respirator Use (See Respirator Policy)

This is not a full list of hazards for which medical surveillance is available. Individuals with questions pertaining to occupational hazards and the possible need for medical surveillance are encouraged to contact the Occupational Medicine Service within the MIT Medical Department. The Occupational Medicine Service in turn works collaboratively with the EHS Office to determine the need for and extent of medical surveillance.

#### Enrollment in Medical Surveillance

For those individuals whose work involves exposures with potential medical surveillance requirements, it is the responsibility of supervisors to identify new employees/students who are exposed to hazards, and to provide names, work addresses, and MIT Identification Numbers (MIT ID) to the EHS Office. Individuals not otherwise identified but who believe that they incur hazardous exposures, or believe they may have been inadvertently omitted, may self-enroll by dialing 617-452-3477. Supervisors who believe that individuals have been inadvertently omitted from medical surveillance may also contact this number. Finally, the EHS Office may identify individuals or populations of individuals at risk and invite their participation.

More information on Medical Consultation, Evaluation, and Surveillance may be obtained from the Medical Department's Occupational Medicine webpage at [http://medweb.mit.edu/directory/services/occupational\\_medicine.html](http://medweb.mit.edu/directory/services/occupational_medicine.html)

### 3.3. Researchers with Medical Conditions

Individuals with medical conditions that could lead to sudden incapacity and who work with hazardous materials or processes during the course of their research may be at increased risk for injury to themselves or others. Anyone with such a medical condition who believes that they may be at increased risk is recommended to contact MIT Occupational Medicine services (E23-171, 253-8552) for consultation and advice on how they may more safely perform their work. Supervisors who have concerns about an individual's health condition and its effect on that person's ability to safely work in a laboratory should also consult with MIT Occupational Medical Services.

Postdoctoral researchers in need of special accommodation as a result of a medical condition should contact the MIT Disability Services Office (E19-215, x4-0082). Students should contact MIT Office of Student Disabilities Services (7-145, x3-1674). Supervisors who have concerns regarding an individual's accommodation requests should contact the appropriate Disabilities Services Office. It is MIT's policy to make every effort to provide reasonable accommodations necessary for researchers to carry out their work.



### 3.4 First Aid Kits and Specific Hazard First Aid

If your Department, Lab or Center (DLC) chooses to have first aid kits in labs, machine shops or other work spaces to treat minor incidental injuries, then there are some additional requirements to address outlined in the First Aid Kit guidance at <https://ehs.mit.edu/wp-content/uploads/EHS-0213.pdf>. The guidance contains information on kit types, maintenance and training. Because medical attention can be reached within a reasonable time on the MIT Campus it is acceptable in most instances to rely on this if first aid is needed and make that part of an emergency plan. In the event of medical emergencies and if you are not sure of severity of the injury or appropriate care call (617) 253-1212 or dial 100 from any MIT phone. Injured personnel not requiring emergency assistance can call MIT's Medical Department Urgent Care in E23 at 617-253-1311 for advice on where to seek care. An injury report must be completed when a first aid kit is used due to an injury/illness <https://ehs.mit.edu/workplace-safety-program/occupational-injury-or-illness-reporting>.

Work environments with specific potential health hazards such as Hydrofluoric Acid should be equipped with appropriate emergency equipment and in certain limited cases, with medical supplies that are readily available and lab personnel trained for immediate application. Contact the EHS Office 617-452-3477 for a hazard assessment and possible recommendation for such special supplies. For a medical emergency and treatment for a confirmed or suspected cyanide exposure we rely on emergency responders by dialing 100 or 617-253-1212 immediately to reach MIT Campus Police. When calling, it is critical to state that it is a potential cyanide exposure and to request a Cambridge Fire Dept. Paramedic Company ambulance service equipped with a CYANOKIT for first aid treatment of cyanide poisoning (See Laboratory Use of Cyanide Salts guidance <https://ehs.mit.edu/chemical-safety-program/chemicals/>).

## 4. EXPOSURE ASSESSMENT (MONITORING & REPORTING)

### 4.1. Exposure Assessment

The EHS Office Industrial Hygiene Program provides exposure assessment services to the Institute community. Exposure assessments are measurements of air contaminants, noise levels, or other health hazards such as heat stress to determine if they are within limits that are considered safe for routine occupational exposure. Employees who believe they have had an exposure should report it to the PI/Supervisor or the EHS Representative. The PI should contact the Chemical Hygiene Officer or the Industrial Hygiene Program (617-452-3477) for an evaluation. The employee can also contact the CHO or the EHS Office directly, but should notify their PI/Supervisor of the situation. In addition, anyone with a reason to believe that exposure levels for a substance routinely exceed the action level, or in the absence of an action level the PEL, may request exposure monitoring. Monitoring may be requested at any time, however, the Chemical Hygiene Officer must be notified of monitoring requests. The Industrial Hygiene Program will conduct, or arrange to have conducted, exposure monitoring.

If the initial monitoring reveals an employee exposure over the action level (or the PEL) for a hazard for which OSHA has developed a specific standard (e.g. lead), the exposure monitoring provisions of that standard, including medical surveillance, shall be followed. It will be the responsibility of the Principal Investigator or Supervisor to insure that necessary periodic monitoring requirements are met.

Within 15 working days after the receipt of any monitoring results, the Industrial Hygiene Program will notify the employee or student of the results in writing, either individually or by posting results in an appropriate location that is accessible to employees. The PI/Supervisor and CHO will also be notified of monitoring results and be provided a copy of a written report. A copy will be kept in the Industrial Hygiene Program's records.

The Industrial Hygiene Program and the Chemical Hygiene Officer will establish and maintain for each employee an accurate record of any measurements taken to monitor exposures. Records, including those from monitoring provided by other qualified services, will be managed in accordance with OSHA standard 29 CFR 1910.1020, Access to Employee Exposure and Medical Records.

## 5. RECORDKEEPING

### 5.1. Exposure Assessment

The Industrial Hygiene Program and the Chemical Hygiene Officer will establish and maintain an accurate record of any measurements taken to monitor exposures. Records, including those from monitoring provided by other qualified services, will be managed in accordance with OSHA standard 29 CFR 1910.1020, Access to Employee Exposure and Medical Records.

### 5.2. Medical Consultation and Examination

Results of medical consultations and examinations will be kept by the MIT Medical Department for a length of time specified by the appropriate medical records standard. This time will be at least the term of employment plus 30 years as required by OSHA.

### 5.3. Training

The PI/Supervisor or designee must keep a copy of the outline of the topics covered in Lab-Specific Chemical Hygiene Training. The roster or lists of researchers who have completed the lab-specific training and read the Chemical Hygiene Plan must be submitted to the EHS Coordinator. These training records are then entered into the EHS-MS central training records database. Web-based training records are automatically entered into the database when a course is completed. The EHS Office is responsible for entering training records into the database for the courses they teach. When an employee or student leaves the Institute, their training records are moved into an archive training database. Training records are kept for at least 3 years after an employee or student leaves the Institute.

### 5.4. Fume Hood Monitoring

Data on annual fume hood monitoring will be kept by the EHS Office. Fume hood monitoring data are considered maintenance records, and as such, the full data will be kept for one year and summary data for 5 years.

### 5.5. Inspection Reports

A copy of the most recent Level II. *Laboratory Inspection Checklist* and *PI Inspection Report*, as outline below, should always be maintained locally within the Department, Laboratory, or Center by the EHS Coordinator. An additional copy will be maintained centrally by the EHS Office.

### 5.6. Lab Specific Policies and SOPs

If Lab Specific SOPs are developed in addition to the SOPs contained in Part II. of this Chemical Hygiene Plan, copies must be maintained in the laboratory accessible to laboratory personnel. In addition, copies of the additional Lab Specific SOPs may be included in Part III. of this Chemical Hygiene Plan.

## 6. LABORATORY INSPECTIONS AND AUDITS, COMPLIANCE AND ENFORCEMENT

### 6.1. Inspections and Audits

As a component of the MIT Environment, Health and Safety Management System (EHS-MS), the Institute has implemented a framework for conducting laboratory/work space inspections and audits to determine laboratory/work space-specific compliance with environment, health, and safety policies, laws, and regulations. The EHS-MS inspections examine a broad spectrum of areas including postings, documentation and training, safety equipment, laboratory/shop protocol, waste, and satellite accumulation areas (SAA).

The purpose of the inspection and audit system is to assist the Institute and laboratories in maintaining a safe work and study environment, ensuring compliance with regulations, identifying the locations where training or retraining is needed, and to fulfill MIT's commitment to environment, health and safety stewardship. This program will satisfy the Department, Laboratory, or Center (DLC) requirements for chemical hygiene inspections.

The MIT EHS-MS requires three levels of inspection and audit that must be implemented across the Institute: **Local Periodic Inspections** (Level I. Inspections), **DLC-Wide Inspections** (Level II. Inspections), **Institutional Audits** (Level III. Audit). For more information on the MIT EHS Inspection and

Audit Program, visit the EHS Management System website at <https://ehs.mit.edu/about/ehs-management-system/> and click on “Inspections” in the *EHS-MS Manual*.

## 6.2. Compliance and Enforcement

Each individual at the Institute is responsible for complying with all MIT, state, and federal rules, regulations, and required procedures; and is held accountable for their actions. If a PI/Supervisor does not take appropriate action to address problems noted during inspection or audits, he or she may be subject to compliance and enforcement action. Issues of non-compliance will be taken to the DLC EHS Committee for recommendations regarding disciplinary action. The EHS Committee will provide recommendations to the Department Head for action. Deliberate failure to comply that results in serious jeopardy to personnel safety and health or the environment may result in loss of laboratory privileges.

A framework for establishing consequences for poor EHS performance and incentives for promoting best management practices has been adopted by the Institute. Visit the EHS Management System website for additional detail at <https://ehs.mit.edu/about/ehs-management-system/> and click on “Roles and Responsibilities” in the *EHS-MS Manual*.

## 7. OSHA HAZARD COMMUNICATION STANDARD (HAZCOM)

[Note: Include this section if this Chemical Hygiene Plan will also be serving to meet the OSHA Hazard Communication requirements for the non-laboratory areas.]

### OSHA Hazard Communication Requirements

This Chemical Hygiene Plan also applies to those areas within this Department, Lab, or Center where hazardous chemicals are used that are not laboratory operations. Such spaces include [Note: List operations here such as machine shops, the kitchens for glassware cleaning, etc.]. All provisions of this Plan apply to these spaces. In addition, for these work areas the PI/Supervisor must:

- ❑ Ensure a list of all hazardous chemicals used in the non-laboratory work area is compiled. The list shall include chemical or product name (as found on the label), manufacturer, location of use or storage, and maximum quantity likely to be present at one time during the year. This list must be updated annually, and a copy of the old list submitted to the EHS Office for archiving.
- ❑ Ensure that for each chemical on the list, there is a copy of an MSDS or SDS in a notebook readily accessible to all personnel using the chemical. This notebook should be updated annually when the list is updated.
- ❑ Ensure all personnel are informed of the chemical list and the MSDS notebook during work area-specific training.

With respect to training, employees and students working in these areas may choose to take *General Chemical Hygiene for Laboratories* or *General HAZCOM* training for non-laboratory areas. They will still need work area-specific training.

With respect to chemical labeling, all potentially hazardous chemicals transferred from their original container to a second container must be labeled with the chemical name and the principal hazard. For more information on labeling, see Part II. Section 6.

Note: Part I, 4 of this document, provides information on changes to the OSHA Hazard Communication Standard that took effect in Spring of 2012, adopting the International Global Harmonization System. This resulted in changes to Safety Data Sheets and chemical labels. Please review that section for more details.

The OSHA hazard communication program reflects the Global Harmonization System (GHS) for classification and labeling of chemicals. Based on OSHA requirements, chemical manufacturers must include the GHS labeling and SDS format for their products, see Appendix 10.2 p. 64. These unique communication tools help lab members to understand the type of hazards quickly. The GHS labels include hazard pictograms, which are image conveying specific information about the hazards of a chemical, and a signal word, either “Danger” or “Warning.” They have standardized language about hazards and precautions, emergency information, and contact information of the manufacturer or distributor.

Nine pictograms are designated for hazard categories under the OSHA. See Appendix 10.3.

## 8. TOXIC SUBSTANCES CONTROL ACT (TSCA)

The Toxic Substances Control Act (TSCA) is a set of EPA regulations (40 CFR 700-799) designed to assess new chemicals for environmental and health risks before they enter the market, and remove existing chemicals from the market if they pose substantial environmental, health and safety risks. Certain laboratory activities may be regulated under TSCA.

MIT developed a streamlined program for complying with the TSCA New Chemicals Program exemption for Research and Development, TSCA Import and Export requirements, and TSCA Allegations of Adverse Effects and Notification of Substantial Risk Reporting. Note: carbon nanotubes are considered “new chemicals” under TSCA.

**Please contact the EHS Office at 617-452-3477 if you:**

- Import a chemical substance
- Export a chemical substance
- Synthesize a new chemical substance, in which case you need to determine if that chemical substance is currently in commerce. If the chemical is not currently in commerce, it must be determined if it is regulated by an existing agency; if it is not regulated by an existing agency, the substance falls under TSCA regulation. Additional TSCA requirements may apply.
- Transfer a new chemical substance to another lab outside your own (on campus or to another facility in the US), you need to determine if the chemical substance is regulated under TSCA. If it is, and little to nothing is known about the environmental and/or health effects of that chemical substance, then TSCA requires you to warn other users of that fact. Labeling requirements for containers apply.
- Are working with a known, commercially distributed chemical and experience unusual health effects or observe unusual environmental effects which are not already documented in the environmental, health and safety risk information currently available
- Are involved in an incident or injury involving a new chemical substance for which little or no environmental, health and safety risk information is available.

**In addition, the following roles and responsibilities help ensure TSCA compliance:**

- Principal Investigators (PIs), as technically qualified individuals with direct supervision over their respective labs, are responsible for ensuring that prudent practices and risk communication are followed in their lab areas; that any experimental efforts and transfer of materials from the lab is consistent with the definition of “research and development activity” outlined in the EHS SOP “Toxic Substances Control Act (TSCA): Procedures for Core Program Compliance” along with the conditions outlined in any research agreements; and, that the Supervisor’s report of Illness and Injury is filed in a timely manner.
- Lab personnel (including PIs) are responsible for following the prudent practices outlined in this Chemical Hygiene Plan; contacting EHS if any of the activities listed above occur; notifying lab mates if they will be handling chemicals for which little or no EHS information is available; and following procedures for reporting incidents/illnesses/injuries.
- The laboratory EHS representative is responsible for either arranging or delivering laboratory-specific chemical hygiene training.
- The Chemical Hygiene Officer is responsible for updating the Department’s Chemical Hygiene Plan; assisting the EHS Coordinator to investigate lab-related incidents/illnesses/injuries; ensuring labs understand chemical risk communication requirements; and forward TSCA-related information to the EHS Office.
- The EHS Coordinator is responsible for reviewing Department training records, and ensuring training is completed on a timely basis.
- The EHS Office is responsible for working with Departments to ensure that any required TSCA forms (Import/Export, Allegations of Adverse Reactions, Notification of Substantial Risk and the TSCA New Chemical Transfer Form) are completed; maintaining TSCA records; ensuring that TSCA compliance

requirements are communicated to the Department; and supporting Chemical Hygiene Officers and EHS Coordinators in conducting incident/illness/injury investigations.

## 9. ANNUAL SARA III CHEMICAL INVENTORY REPORTING

The Superfund Amendments and Reauthorization Act (SARA) Title III regulations were developed by the EPA to deal with the release of hazardous materials into the community, emergency response planning, and community right to know. A section of these regulations requires that all facilities in a community using hazardous chemicals report **aggregate** quantities greater than the “Threshold Planning Quantity” (TPQ) to local fire departments, the Local Emergency Planning Committee, and the Massachusetts State Department of Environmental Protection. The purpose is to give fire fighters and emergency responders information on what is inside a facility before an emergency occurs.

To comply with this regulation, MIT submits a chemical inventory each year by March 1 that covers both its facilities and laboratory operations. **The Chemical Reporter in each laboratory receives a list of applicable chemicals in fall of each year. The quantity of each listed chemical on hand must be inventoried and reported back to the EHS Office. Chemical reporting MUST be done through Atlas or requesting EHS to submit the report for the lab.** The EHS Office tabulates **the aggregate quantities** for the entire campus and reports total amounts and amounts by location to the required authorities. Note that most of the SARA Inventory chemicals are *particularly hazardous substances* (as defined by OSHA). The SARA Inventory Report includes only those chemicals that are in wide use on campus **above aggregate TPQs and** is most likely only a partial list of all the *particularly hazardous substances* that may be in use in a lab.

**The lab is required to maintain a list of all *particularly hazardous substances* in use in their laboratories, including an inventory of the maximum quantity present at any given time. See Part II section 3.3.10 p. 33. For more information please visit <https://ehs.mit.edu/chemical-safety-program/chemical-regulatory-reporting-security/>**

## 10. Appendix

### 10.1. DHS List of 41 Chemicals With Low Threshold Reporting Quantities That Require Prior Approval From The DLC EHS Coordinator or DLC EHS Committee Before Purchasing

Chemical of Interest	Synonym	Chemical Abstract Service (CAS) Number	Screening Threshold Quantity (lbs)
1,4-bis(2-chloroethylthio)-n-butane		142868-93-7	100g
bis(2-chloroethylthio)methane		63869-13-6	100g
bis(2-chloroethylthioethyl)ether		63918-89-8	100g
1,5-bis(2-chloroethylthio)-n-pentane		142868-94-8	100g
1,3-bis(2-chloroethylthio)-n-propane		63905-10-2	100g
2-chloroethylchloromethylsulfide		2625-76-5	100g
Chlorosarin		1445-76-7	100g
Chlorosoman		7040-57-5	100g

DF	Methyl phosphonyl difluoride	676-99-3	100g
N,N-(2-diethylamino)ethanethiol		100-38-9	2.2
o,o-Diethyl S-[2-(diethylamino)ethyl] phosphorothiolate		78-53-5	2
Diethyl methylphosphonate		15715-41-0	2
N,N-Diethyl phosphoramidic dichloride		1498-54-0	2
N,N-(2-diisopropylamino)ethanethiol		5842-07-9	2
N,N-Diisopropyl phosphoramidic dichloride		23306-80-1	2
N,N-(2-dimethylamino)ethanethiol		108-02-1	2
N,N-Dimethyl phosphoramidic dichloride		677-43-0	2
N,N-(2-dipropylamino)ethanethiol		5842-06-8	2
Ethyl phosphonyl difluoride		753-98-0	100g
Ethylphosphonothioic dichloride		993-43-1	2
HN1 (nitrogen mustard-1)	Bis(2-chloroethyl)ethylamine	538-07-8	100g
HN2 (nitrogen mustard-2)	Bis(2-chloroethyl)methylamine	51-75-2	100g
HN3 (nitrogen mustard-3)	Tris(2-chloroethyl)amine	555-77-1	100g
Isopropylphosphonothioic dichloride		1498-60-8	2
Isopropylphosphonyl difluoride		677-42-9	100g
Lewisite 1	2-Chlorovinylchloroarsine	541-25-3	100g
Lewisite 2	Bis (2-Chlorovinyl)chloroarsine	40334-69-8	100g
Lewisite 3	Tris (2-Chlorovinyl)chloroarsine	40334-70-1	100g
Methylphosphonothioic dichloride		676-98-2	2
Sulfur Mustard (mustard gas (H))	Bis (2-chloroethyl) sulfide	505-60-2	100g
O-Mustard (T)	Bis (2-chloroethioethyl) ether	63918-89-8	100g
Nitrogen mustard hydrochloride	Bis (2-chloroethyl)methylamine hydrochloride	55-86-7	2

Propylphosphonothioic dichloride		2524-01-8	2
Propylphosphonyl difluoride		690-14-2	100g
Sarin	o-Isopropyl methylphosphonofluoridate	107-44-8	100g
Sesquimustard	1,2-Bis(2-chloroethylthio) ethane	3563-36-8	100g
Soman	o-Pinacolyl methylphosphonofluoridate	96-64-0	100g
Tabun	o-Ethyl-N,N-dimethylphosphoramido-cyanidate	77-81-6	100g
Thiodiglycol		111-48-8	2
VX	o-ethyl-S-2-diisopropylaminoethyl methyl phosphonothiolate	50782-69-9	100g

## Appendix 10.2

Taken from OSHA website at:

[http://www.osha.gov/Publications/HazComm\\_QuickCard\\_SafetyData.html](http://www.osha.gov/Publications/HazComm_QuickCard_SafetyData.html)

### Hazard Communication Safety Data Sheets – New Format

The Hazard Communication Standard (HCS) requires chemical manufacturers, distributors, or importers to provide Safety Data Sheets (SDSs) (formerly known as Material Safety Data Sheets or MSDSs) to communicate the hazards of hazardous chemical products. As of June 1, 2015, the HCS will require new SDSs to be in a uniform format, and include the section numbers, the headings, and associated information under the headings 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(s) 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 important 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 Permissible Exposure Limits (PELs); Threshold Limit Values (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.

\*Note: Since other Agencies regulate this information, OSHA will not be enforcing Sections 12 through 15(29 CFR 1910.1200(g)(2)).

**This is the new standard format for what will now be called Safety Data Sheets, not Material Safety Data Sheets. More details about content are at <http://www.osha.gov/dsg/hazcom/index.html>. Some chemical suppliers are already using this format. If you have questions about information or interpretation, contact the MIT EHS Office at 617-452-3477 or [environment@mit.edu](mailto:environment@mit.edu).**










### 10.3 Hazard Communication Standard Pictogram

Taken from OSHA website at: [http://www.osha.gov/Publications/HazComm\\_QuickCard\\_Pictogram.html](http://www.osha.gov/Publications/HazComm_QuickCard_Pictogram.html)

#### HCS Pictograms and Hazards

The Hazard Communication Standard (HCS) require pictograms on labels to alert users of the chemical hazards to which they may be exposed. Each pictogram consists of a symbol on a white background framed within a red border and represents a distinct hazard(s). The pictogram on the label is determined by the chemical hazard classification.

<p><b>Health Hazard</b></p>  <ul style="list-style-type: none"><li>• Carcinogen</li><li>• Mutagenicity</li><li>• Reproductive Toxicity</li><li>• Respiratory Sensitizer</li><li>• Target Organ Toxicity</li><li>• Aspiration Toxicity</li></ul>	<p><b>Flame</b></p>  <ul style="list-style-type: none"><li>• Flammables</li><li>• Pyrophorics</li><li>• Self-Heating</li><li>• Emits Flammable Gas</li><li>• Self-Reactives</li><li>• Organic Peroxides</li></ul>	<p><b>Exclamation Mark</b></p>  <ul style="list-style-type: none"><li>• Irritant (skin and eye)</li><li>• Skin Sensitizer</li><li>• Acute Toxicity (harmful)</li><li>• Narcotic Effects</li><li>• Respiratory Tract Irritant</li><li>• Hazardous to Ozone Layer (Non-Mandatory)</li></ul>
<p><b>Gas Cylinder</b></p>  <ul style="list-style-type: none"><li>• Gases Under Pressure</li></ul>	<p><b>Corrosion</b></p>  <ul style="list-style-type: none"><li>• Skin Corrosion/ Burns</li><li>• Eye Damage</li><li>• Corrosive to Metals</li></ul>	<p><b>Exploding Bomb</b></p>  <ul style="list-style-type: none"><li>• Explosives</li><li>• Self-Reactives</li><li>• Organic Peroxides</li></ul>
<p><b>Flame Over Circle</b></p>  <ul style="list-style-type: none"><li>• Oxidizers</li></ul>	<p><b>Environment (Non-Mandatory)</b></p>  <ul style="list-style-type: none"><li>• Aquatic Toxicity</li></ul>	<p><b>Skull and Crossbones</b></p>  <ul style="list-style-type: none"><li>• Acute Toxicity (fatal or toxic)</li></ul>