Caltech

CALIFORNIA INSTITUTE OF TECHNOLOGY
CHEMICAL HYGIENE PLAN

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INTRODUCTION

The purpose of California Institute of Technology's (Caltech) Chemical Hygiene Plan (CHP) is to establish a written program that provides for and supports the procedures, equipment, personal protective equipment, and work practices for protecting laboratory personnel from potential health hazards of using hazardous chemicals in the laboratory.

The CHP is designed to comply with the regulations of California's Occupational Safety and Health Administration (Cal/OSHA) *Occupational Exposure to Hazardous Chemicals in Laboratories*, Title 8- California Code of Regulations, Section 5191 http://www.dir.ca.gov/title8/5191.html.

Components of the CHP include:

- Responsible personnel
- Standard Operating Procedures (SOPs)
- Engineering control measures
- Proper operation of engineering controls
- Training and information
- Medical examination and consultation

The objective of the CHP is to:

- Protect the health and safety of Caltech faculty, staff, students, and visitors.
- Provide safe work practices – academic, research, and administrative – for faculty, staff, students, and visitors.
- Provide information to faculty, staff, students, and visitors about health and safety hazards.
- Identify and reduce risk from health and safety hazards.
- Encourage faculty, staff, and students to report hazards.
- Provide information and safeguards for campus and in the surrounding community regarding environmental hazards arising from operations at Caltech.

ROLES & RESPONSIBILITIES

Department Chair

Provide or obtain administrative and financial support, as needed, for implementing and maintaining the CHP.

Principal Investigator/Laboratory Supervisor

The Principal Investigator (PI)/Laboratory Supervisor is responsible for the health and safety of laboratory personnel doing work in the laboratory.

The PI/Laboratory Supervisor may delegate the safety duties but not the responsibility, and must make sure that any delegated safety duties are carried out**.**

The PI/Laboratory Supervisor's responsibilities include:

- Implement and apply the Chemical Hygiene Program.
- Ensure that SOPs are in place for using hazardous chemicals (including toxic gases and select agents), emergency procedures, decontamination procedures, and waste handling are developed, available, and followed.
- Ensure appropriate training is given at a timely matter.

- Ensure access to SDSs of hazardous materials used in the laboratory.
- Ensure workplace controls (e.g., fume hoods) and safety equipment (e.g., emergency showers/eyewashes, fire extinguishers) are in functional working order, with emphasis on controls for particularly hazardous substances.
- Ensure that appropriate personal protective equipment and apparel is available, functioning properly, and used as required and/or needed.
- Ensure that the information regarding the laboratory activities and inventory are recorded on the NFPA signs posted outside each lab. This should include emergency contact information to be used in case of an emergency.
- Investigates and reports to the EHS Office any problems pertaining to the operation and implementation of laboratory practices and engineering controls.
- Identifies laboratory operations, procedures, and activities that require prior approval; designating the approval authority.

Laboratory Safety Officers

- Each PI overseeing a research laboratory may designate a Laboratory Safety Officer.
- Day to day details may be delegated to the Laboratory Safety Officer.
- Duties may include but are not limited to:
  1. Promulgate EHS safety information
  2. Provide lab-specific orientation to new lab members
  3. Act as a technical resource to lab personnel
  4. Act as the emergency coordinator
  5. Conduct periodic laboratory inspections

Laboratory Personnel

All Laboratory Personnel who work with hazardous chemicals in research laboratories are responsible for:

- Complying with oral and written safety rules, regulations, and procedures required for the task assigned.
- Knowing and understanding the hazards of materials and processes prior to conducting work and utilizing appropriate measures to control these hazards.
- Attending necessary or required training.
- Evaluating, maintaining, and using personal protective equipment (PPE).
- Participating in medical surveillance when required.
- Reporting unsafe conditions to the PI or immediate supervisor.
- Informing the PI/Laboratory Supervisor of any work modifications ordered by a physician as a result of exposure.
- Keeping the work areas safe and uncluttered.

Division Administrator

For buildings in which laboratory research involving chemicals are conducted, the Division Administrator is responsible for:

- Being familiar with the CHP and its content and objectives.
- Assist in inspections, incident investigations, and facilities issues.

Environment, Health, and Safety

Caltech's occupational health and safety program at Environment, Health, and Safety (EHS) is responsible for administering and overseeing institutional implementation of the CHP. EHS provides technical guidance and

resources (i.e., consulting and training materials) to personnel at all levels of responsibility on matters pertaining to laboratory use of hazardous chemicals.

For other health and safety assistance in the lab (i.e., Biosafety, Radiological Safety, and Hazardous Waste) visit the EHS website at http://www.safety.caltech.edu.

EHS, which includes a Chemical Hygiene Officer (CHO), is responsible for providing technical guidance on matters pertaining to laboratory safety, including ergonomics.

- Assists the PI/Supervisor with hazard assessments of the overall operation to determine the appropriate safety control requirements, including laboratory practices, personal protective equipment, engineering controls, and training.
- Assists PI in the selection of control methods.
- Performs industrial hygiene monitoring for evidence of personnel exposure and/or equipment contamination.
- Reviews chemical procedures as needed.
- Reviews chemical inventories from laboratories, as needed.
- Determines medical surveillance requirements for personnel.
- Maintains employee exposure monitoring and medical surveillance records.
- Reviews plans for new laboratory construction, renovation, or installation of engineering controls, as needed.
- Provides ergonomics services, including performing ergonomic evaluations, recommending equipment and work practices, and providing training.
- Reviews and evaluates the effectiveness of the CHP at least annually and updating it, as necessary.
- Knows and complies with applicable Federal, State, and Local regulations.
- Maintains hazardous materials inventory databases and generates necessary regulatory reporting.
- Provides technical assistance on storage, classification, compatibility, and SDSs.
- Performs observational surveys of laboratories and proposes corrective actions.
- Identifies concerns or gaps in compliance.

Administrative, Maintenance, and Custodial Personnel

For buildings in which laboratory research involving hazardous chemicals is conducted, administrative personnel, maintenance (e.g., plumbers and HVAC technicians), and custodial staff are responsible for:

- Attending Hazard Communication Training, which familiarizes them with the potential hazards of performing administrative, maintenance, or janitorial tasks in a laboratory.
- Reporting unsafe conditions to their immediate supervisor.

Facilities Design and Construction

Caltech Project Managers assigned to new construction, renovations, and installations of engineering controls are responsible for:

- Submitting plans for review to EHS for laboratory construction, renovation, or installation of engineering controls.
- Complying with applicable Federal, State, and Local regulations regarding laboratory construction, renovation, or installation of engineering controls.
- Commission the laboratory including engineering controls and equipment.

STANDARD OPERATING PROCEDURES

Laboratory-Specific SOPs

The PI/Lab Supervisor is responsible for providing written Standard Operating Procedures (SOPs) for specific laboratory practices involving hazardous chemicals. As needed, the EHS Office will review these SOPs. The PI must ensure that laboratory personnel are trained on the use of SOPs applicable to their activities.

General Health and Safety Procedures for Laboratories

Presented in General Health and Safety Practices are general procedures applicable for the use, and handling, of chemicals in all laboratories. Also, within these general procedures are guidelines which are applicable to non-chemical activities in laboratories. The PI/Lab Supervisor is responsible to ensure that all employees are trained in the use of these procedures.

Hazardous Waste Management

Management of hazardous waste is a critical health and safety and compliance responsibility of the laboratory. The Hazardous Waste Program encourages the recycling of chemicals, if appropriate, and ensures that hazardous chemical wastes are properly collected, packaged, shipped, and disposed. Please see General Health and Safety Practices SP11: Hazardous Waste Guidelines.

Storage and Inventory

All Hazardous Chemicals

Proper storage of chemicals is necessary to prevent spills and undesirable reactions. Maintaining an inventory of chemicals facilitates the elimination of excess or outdated chemicals and provides more efficient use of laboratory storage space. Please see General Health and Safety Practices SP6: Chemical Storage.

Select Agent Toxins

Possession and use of Department of Health and Human Services toxins must comply with CDC Select Agents Regulations (42 CFR Part 73). Please see http://www.selectagents.gov for more information.

Controlled Substances and Chemical Precursors

The registration, procurement, inventory, storage, record keeping, use, and disposal of controlled substances and chemical precursors must comply fully with all applicable Federal and State laws and regulations and the Caltech Policy on Controlled Substances and Chemical Precursors. This policy and additional information are available at http://safety.caltech.edu/services/controlled_substances.

Emergency Response – Spills and Exposures

All incidents involving hazardous chemical spills and exposures require prompt action by the responders and the injured in order to control chemical exposures to personnel and to minimize impacts to the environment and property. Guidelines are available on the EHS website at:
http://safety.caltech.edu/manuals/emergency_response_guide.

HAZARD RECOGNITION

The PI/Lab Supervisor with assistance from the EHS Office is responsible for understanding the hazards related to the use, storage, and disposal of laboratory chemicals. The most important aspect to the recognition process is ensuring that laboratory personnel have access to Safety Data Sheets (SDSs).

Safety Data Sheets

Safety Data Sheets (SDSs) are documents prepared by the chemical manufacturer that contain the following information:

- Identify the product and manufacturer
- Ingredients, percentages, and exposure limits, where appropriate
- Physical properties, fire and explosion hazards, and reactivity data
- Health hazards
- Release, spill, and disposal information
- Personal Protective Equipment
- Handling and storage procedures

The PI/Lab Supervisor with the assistance of the EHS Office is responsible for ensuring that SDSs are readily available. SDSs are available for most laboratory chemicals used at Caltech at the EHS website http://www.safety.caltech.edu/sds. For those chemicals for which SDSs are not available on this website, SDSs must be obtained and maintained at the laboratory where the chemicals are used.

The PI/Lab Supervisor with the assistance of the EHS Office is responsible for providing training regarding SDS retrieval online and documenting the training.

Labeling of Chemicals

All Hazardous chemical manufacturers are required to label chemical containers with the following:

- Identity of the hazardous chemical or mixture
- Hazard warning(s)
- Name and address of the manufacturers, importer, or other responsible party

Chemical users should:

- Ensure manufacturers' labels on new containers are not removed or defaced
- Clearly mark the dates the chemical containers are received and opened on the chemical containers
- Properly label "in-house" containers with a chemical name when transferring chemicals
- Properly label waste containers and ensure that each has a hazardous waste identification tag

General Classes of Hazardous Chemicals

Chemicals have inherent physical, chemical, and toxicological properties that require laboratory personnel to have a good understanding of the related health and safety hazards. The main types of chemical hazards that lab personnel should be aware of are below.

Flammable and Combustible Liquids

In general, the flammability of a chemical is determined by its flash point, the lowest temperature at which an ignition source can cause the chemical to ignite momentarily.

- Chemicals with a flash point below 200^{o} F (93.3^{o} C) are considered "fire-hazard chemicals"

- Fire-hazard chemicals should be stored in a flammable solvent storage area or in storage cabinets designed for flammable materials
- Fire-hazard chemicals should be used only in vented hoods and away from sources of ignition

Flammable Liquid Storage

- Store flammable liquids in excess of 10 gallons in approved flammable liquid storage cabinets
- Storage of flammable liquids outside of a cabinet should be in an approved flammable liquid container or in its DOT-approved container with secondary containment

Corrosive and Contact-Hazard Materials

Corrosive, allergenic, and sensitizer information is given in SDSs and on chemical container labels. Also, guidelines on how to handle corrosive chemicals can be found in the OSHA and DOT standards.

A corrosive chemical is one that:

- Fits this OSHA definition: A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact
- Has a pH greater than 12 or less than 2.5
- Is known or found to be corrosive to living tissue

A contact-hazard chemical is an allergen or sensitizer that:

- Is so identified or described in the SDS or on the label
- Is so identified or described in medical- or industrial-hygiene literature
- Is known or found to be an allergen or sensitizer

Handle corrosive chemicals and contact-hazard chemicals with all proper safety precautions, including wearing both safety goggles and face shield, gloves tested for absence of pinholes and known to be resistant to permeation or penetration, and a laboratory apron or laboratory coat. (See Table 3: Chemical Resistance Chart).

Highly Reactive/Unstable Materials Reactive Chemicals

Reactive chemicals are those that are:

- Described as such in the Safety Data Sheet
- Ranked by the NFPA as 3 or 4 for reactivity
- Identified by the DOT as an oxidizer, an organic peroxide, or an explosive
- Known or found to be reactive with other substances

Handle reactive chemicals with the proper safety precautions as described in the chemical's Safety Data Sheet.

Compressed Gases/Cryogenic Liquids and Toxic Gases

Compressed gases and cryogenic liquids are similar in that they can create pressure hazards and can also create health hazardous and/or flammable atmospheres. One special property of compressed gases and cryogenic liquids is that they undergo substantial volume expansion when released to air, potentially depleting workplace oxygen content to hazardous levels.

See General Health & Safety Practices, SP8: Compressed Gas Cylinders.

See General Health & Safety Practices, SP12: Working with Cryogenics.

Cal/OSHA "Particularly Hazardous Substances"

Specific carcinogens, reproductive toxins, and chemicals with high acute toxicity (also known as "highly toxic") are considered to be high-risk materials and are treated by Cal/OSHA as "Particularly Hazardous Substances." See Table 1 for additional information about Particularly Hazardous Substances.

> ***Carcinogens*** are chemicals or physical agents that cause cancer or tumor development, typically after repeated or chronic exposure. Their effects may only become evident after a long latency period and may cause no immediate harmful effects.
>
> ***Reproductive Toxins*** include substances that cause chromosomal damage (mutations) or lethal or malformation effects on fetuses (teratogenesis). Many reproductive toxins cause damage after repeated low-level exposures. Effects become evident after long latency periods.
>
> ***Highly Toxic Chemicals*** with a high level of acute toxicity have the ability to cause harmful local and systemic effects after a single exposure. Many of these chemicals may also be characterized as a toxic gas, CDC Select Agent Toxin, corrosive, irritant, or sensitizer.

Nanomaterials and Nanoparticles

A nanoparticle is a collection of tens to thousands of atoms approximately 1 to 100 nanometers in diameter. Nanoparticles that are naturally occurring (e.g., volcanic ash, forest fires) or are the incidental byproducts of combustion processes (e.g., welding, diesel engines) are usually physically and chemically heterogeneous and often termed ultrafine particles. Engineered nanoparticles are intentionally produced and designed with very specific properties related to shape, size, surface properties, and chemistry. These properties are reflected in aerosols, colloids, or powders. Engineered nanoparticles may be bought via commercial vendors or generated via experimental procedures by researchers in the laboratory. Examples of engineered nanomaterials include: carbon buckeyballs or fullerenes; carbon nanotubes; metal oxide nanoparticles (e.g., titanium dioxide); and quantum dots, among many others.

The health effects of exposures to nanomaterials are not fully understood at this time. Until more definitive findings are made regarding the potential health risks of handling nanomaterials, researchers planning to work with nanomaterials must implement a combination of engineering controls, work practices, and personal protective equipment to minimize potential exposures to themselves and others. See the EHS website www.safety.caltech.edu.

Laboratory Developed Chemicals

Chemicals produced in the laboratory require special consideration.

- If the composition of the chemical substance is known and it is produced exclusively for the laboratory's own use, the PI will determine if it is hazardous.
- If the chemical is produced as a byproduct whose composition is not known, it shall be assumed to be hazardous.

New Procedures, Equipment, and Particularly Hazardous Materials

Evaluate any new or hazardous procedure with the PI/Laboratory Supervisor and Safety Officer. The EHS Office is also available for consultation (See SP9: New Procedures and Planning an Experiment).

ENGINEERING & ADMINISTRATIVE CONTROL CRITERIA AND VERIFICATION

Engineering and administrative controls are important and effective methods for limiting personnel exposure to chemicals. The most effective way to prevent adverse health effects from chemical exposure is to substitute less hazardous chemicals. (For example, substitute toluene for benzene or use aqueous soap instead of an organic solvent for cleaning). Note that substitution is not always practical or feasible in research laboratory operations; therefore the following controls can be implemented:

Engineering Controls

Chemical safety is achieved by an acute awareness of chemical hazards, by understanding how to keep chemical reactions under control, and by using precautions, including engineering controls such as fume hoods. Laboratory supervisors should be knowledgeable and vigilant about the failure modes of engineering controls and safeguards. All engineering safeguards and controls must be properly maintained, inspected regularly, and never exceed or be overloaded beyond their design limits.

The following engineering controls play a critical role in protecting employees and the environment:

- Chemical fume hoods, glove boxes, closed systems, and other isolated devices. Note that fume hoods shall comply with 8 CCR 5154.1, Ventilation Requirements for Laboratory Type Hood operations http://www.dir.ca.gov/title8/5154_1.html.
- Air contaminant removal devices (e.g., cold traps, HEPA filters) to minimize contamination of exhaust ventilation to the exterior environment.
- Negative air pressure of the work place relative to common areas.
- Non-permeable work surfaces.
- Secondary containment trays.
- Always work with toxic chemicals in a fume hood.

Performance Verification of Engineering Controls and Equipment

Engineering controls and equipment must function properly at all times in order to protect the health and safety of laboratory employees. This equipment is tested according to the following schedule:

Equipment	Testing Frequency (minimum)	Responsible Party	California Standards
Eyewash	Monthly	Plumbing Shop	8 CCR 5162
Safety Shower	Monthly	Plumbing Shop	8 CCR 5162
Fume Hoods*	Annually	EHS HVAC Shop	8 CCR 5154.1 8 CCR 5143
HVAC System	Annually	HVAC Shop	Per design specifications
Fire Extinguishers	Visual Inspection Monthly	EHS	8 CCR 6151 19 CCR 574.5

***Note:** Verify posted certification sticker on fume hood is current before using.

Administrative Controls

The following administrative controls may be used to minimize employee exposure to hazardous chemicals:

- Rigorously follow SOPs when conducting laboratory work involving hazardous chemicals. Follow general laboratory safety and health procedures (see General Health and Safety Practices).
- Review plans for new and renovated work areas and laboratory equipment prior to installation or construction.
- Substitute more robust equipment (e.g., using safety cans instead of glass bottles).

- Scale the size of the experiment.
- Isolate the operator or process.
- Obtain prior approval and/or critical review for laboratory activities involving particularly hazardous substances or procedures.

Designated Areas

A designated area is a segregated space within a lab for work with select carcinogens, reproductive toxins, and other materials with a high degree of acute toxicity (See Table 1: Select Carcinogens, Reproductive Toxins, and Compounds with a High Degree of Acute Toxicity). A designated area may be a hood, glove box, portion of a laboratory, or an entire laboratory room where specific chemicals are used. Only properly trained lab workers are allowed to handle regulated chemicals in designated areas.

Within the designated area, remember to follow these guidelines:

- Use the smallest amount of the material that is consistent with the requirements of the work to be done.
- Remove chemicals from storage only as needed and return them to storage as soon as practical.
- Decontaminate the designated area when work is complete.
- Store all hazardous chemicals in a secured area.

PERSONAL PROTECTIVE EQUIPMENT

Personal Protective Equipment (PPE) is considered a last resort for protecting employee health and safety and is used only if substitution, engineering, and/or administrative controls are not feasible. Employees must be trained on the proper use and care of PPE. Consult the SDS, PI/Laboratory Supervisor or EHS to determine the correct PPE for the chemical process. Please see SP3: Personal Protective Equipment Guidelines.

Types of PPE

PPE is available in the campus stockrooms. The following PPE is required in chemical laboratories based on the laboratory's hazard assessment:

- Eye and face protection includes:
  - Safety glasses with side shields, chemical splash goggles, and face shield. Prescription safety glasses can be obtained by contacting the EHS Office (Supervisor approval required).
- Skin protection includes:
  - Laboratory coat, chemical resistant gloves, closed-toed shoes, long sleeved shirts, long legged trousers, chemical splash apron, arm covers, head covers, and total body suits.
- Respiratory protection includes:
  - Air purifying half-face or full-face respirators are used when necessary to maintain exposure below the Permissible Exposure Limit (PEL).
  - Employees may only use respirators if they have been trained, fit-tested, cleared by a physician, and authorized by EHS.
  - Respirators shall be selected and used in accordance with 8 CCR 5144.
  - Respiratory fit testing is arranged by contacting EHS at extension 6727.
- Hearing protection:
  - Earplugs and earmuffs.

Ensuring PPE Performance

PPE must function properly at all times in order to protect the health and safety of laboratory employees. PPE equipment therefore must be properly maintained and inspected according to the following schedule:

Equipment	Testing Frequency (minimum)	Responsible Party	Standard
PPE (i.e., gloves, safety glasses, respirators)	Visual inspection at each use	Laboratory	8 CCR 3380-3385
Respirators	Visual inspection at each use	Laboratory	8 CCR 5144

TRAINING AND RECORDKEEPING

Laboratory Personnel Training and Recordkeeping

Laboratory Personnel must be trained to understand the hazards of the chemicals with which they work. General chemical hygiene training is available through the EHS Office. Laboratory specific training is the responsibility of the PI, who may delegate the training duties to a member of the lab staff.

Training Frequency

Training will be provided:

- Upon initial assignment to a work area where a hazardous chemical or process is present.
- Upon introduction of new hazards into the work area.

Contents of the Training

Employees will be trained on and informed of:

- Location, availability, and applicable details of this Plan.
- Relevant exposure limits for hazardous chemicals.
- Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory.
- Methods and observations to detect the presence or release of hazardous chemicals.
- The physical, chemical, and health hazards of the chemicals in the work area.
- Measures employees can take to protect themselves from hazards.
- The location and availability of relevant reference materials on the hazards, safe handling, storage, and disposal of hazardous materials. This includes, but is not limited to, the SDSs received from the chemical supplier. Note that most of this information is available online at www.safety.caltech.edu.

Training Recordkeeping

Lab-specific training records shall be maintained by the PI/Group Safety Officer and/or the Division Administrator.

EHS maintains permanent records of the following:

- Environmental monitoring results when determining the presence and concentration of hazardous substances in laboratories and other campus facilities.
- Fume-hood performance in laboratories.
- Physical examinations done in response to real or suspected exposure to hazardous materials.
- Results of incident investigations and recommendations for actions to minimize the risk of a recurrence.
- Other records required by regulatory agencies (OSHA, EPA, California Department of Health Services, et.al.).

PERMISSIBLE EXPOSURE LIMITS

OSHA sets enforceable permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air. They may also contain a skin and eye absorption designation. OSHA PELs are based on an 8-hour time weighted average (TWA) exposure.

OSHA established PELs can be found by referring to a chemical's Safety Data Sheet (SDS).

MONITORING AND MEDICAL SURVEILLANCE

The handling, use, and proper storage of highly hazardous chemicals, such as toxic chemicals, carcinogens, and reproductive toxins, may require that laboratory personnel be monitored for exposure. Medical consultations, examinations, and testing are provided to personnel who may have been exposed to hazardous chemicals. Medical surveillance is provided to personnel who work with certain chemicals or whose work potentially involves chemical concentrations that may be above regulatory and/or consensus standards. SP10: Medical Surveillance provides guidance on the medical surveillance process.

Chemical Exposure Monitoring

Monitoring Assessment

Based on a hazard assessment and/or a workplace evaluation, EHS may conduct the following types of personnel monitoring to assess potential chemical exposures:

- Personal
- General area/or Process
- Surface

Personal Monitoring

Personal monitoring is conducted to determine exposure levels or the need for medical consultation, examination, and/or surveillance.

EHS shall measure personal exposure to any chemical regulated by a standard which requires monitoring or if there is reason to believe that exposure levels for that substance may exceed the action level or exposure limit. Examples where personal monitoring may be conducted include when (1) personnel develop signs or symptoms associated with hazardous chemicals and/or (2) suspected exposure.

- If the action level or exposure limit is exceeded during the initial monitoring, personal monitoring will be repeated per the relevant regulatory standards or consensus guidelines.
- Monitoring may be terminated in accordance with relevant regulatory standards or consensus guidelines.
- Monitoring results will be provided to personnel.
- Where exposure monitoring reveals an exposure above the action level (or in the absence of an action level, the exposure limit) for a Cal/OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance will be established as prescribed therein.

General Area or Process Monitoring

- General area or process monitoring is conducted to augment personal monitoring and to aid in the assessment of the effectiveness of engineering controls.

Surface Monitoring

- Surface monitoring is conducted to augment personal, area, and process monitoring and to evaluate contamination control and the effectiveness of decontamination practices.

Recordkeeping of Exposure Monitoring

- EHS will maintain records of personnel exposure monitoring.
- Employees will have access to exposure records.

Medical Consultation, Examination, and Surveillance

- Personnel who work with hazardous chemicals will be provided the opportunity to receive medical attention when:
    - Symptoms or signs develop.
    - Exposure monitoring reveals an overexposure.
    - A spill, leak, explosion, or other occurrence results in a hazardous exposure (potential overexposure).
- Medical examinations will be conducted by a licensed physician and will be provided at a reasonable time and place at no cost to the employee.
- The Laboratory Group will provide the following information to the physician:
    - Identity of hazardous chemicals.
    - Conditions of exposure, including exposure data.
    - Signs and symptoms of exposure.
- EHS will obtain a written report from the physician which includes:
    - Examination and test results.
    - Any medical condition, which may place employee at increased risk from workplace hazardous chemicals.
    - The written report **shall not** reveal specific findings of diagnoses unrelated to occupational exposure.

Note: Employees are responsible for informing the PI/Laboratory Supervisor of any work modifications ordered by the physician as a result of exposure.

Recordkeeping of Medical Consultations, Examinations, and Surveillance

- Medical records will be maintained by the Institute Workers Compensation Department.
- Employees **shall** have access to their personal medical records.

GLOSSARY

Definitions and Acronyms

29 CFR Parts 1910.1450 – Section of the Code of Federal Regulations: Occupational Exposures to Hazardous Chemicals in Laboratories.

8 CCR 5191 – Section of the California Code of Regulations covering: Occupational Exposure to Hazardous Chemicals in Laboratories.

8 CCR 514.1 – Section of the California Code of Regulations covering: Ventilation Requirements for Laboratory – Type Hood Operations.

ACGIH – American Conference of Governmental Industrial Hygienists: an organization of professional personnel in governmental agencies or educational institutions who are employed in occupational safety and health programs.

ANSI – American National Standards Institute.

ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

BDT - Breakthrough detection times.

Cal/OSHA Action Level – The exposure level (concentration of the material in air) at which Cal-OSHA regulations to protect employees take effect.

Cal/OSHA Regulated Carcinogen – A carcinogen specifically listed in Title 8 CCR 5209.

Carcinogen – A substance or agent capable of causing or producing cancer in mammals, including humans. A chemical is considered to be a carcinogen if:

1. It has been evaluated by the International Agency for Research on Cancer (IARC) and found to be a carcinogen or potential carcinogen; or
2. It is listed as a carcinogen or potential carcinogen in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) latest edition; or
3. It is regulated by OSHA as a carcinogen.

Chemical Hygiene Plan – A written program that sets forth policy and procedures capable of protecting employees from the health hazards associated with their workplace.

Chemical Waste Program – Caltech EHS unit designed to properly collect and dispose of hazardous waste.

CCR – California Code of Regulations, Title 8 – Industrial Relations, contains the regulations enforced by Cal-OSHA.

CHO – Chemical Hygiene Officer.

CGA – Compressed Gas Association.

CFR – Code of Federal Regulations.

CPC – Chemical Protection Clothing.

DOSH – Division of Occupational Safety and Health.

EHS – Environment Health and Safety Department at California Institute of Technology.

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

EPA – US Environmental Protection Agency.

Exposure Limits – The concentration in air of a chemical in the workplace that is thought to be acceptable.

Hazard Assessment – Determination of the potential health hazards associated with an experiment before beginning it.

Hazardous Chemical (as defined in 8 CCR 5191) – 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 (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).

Hazardous Material – Includes Hazardous Chemicals, Biohazardous, and Radioactive Materials.

HCS – Hazard Communications Standard: an OSHA regulation issued under 29 CFR Part 1910.1200.

HCSC – Campus Hazardous Chemical Safety Committee.

HEPA filter – High-efficiency particulate air-purifying filter.

Highly Toxic – A chemical falling within any of the following categories:

1. A chemical with a median lethal dose (LD50) of 50 mg or less per Kg of body weight when administered orally to albino rats weighing between 200 and 300 gm each.
2. A chemical with a median lethal dose (LD50) of 200mg or less per Kg of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 Kg each.
3. A chemical that has a medial lethal concentration (LC50) in air of 200 ppm by volume or less of gas or vapor, or mg per liter or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 gm each.

HVAC – Heating, ventilation, and air-conditioning system.

Health Hazards – Have properties capable of producing adverse effects on the health and safety of a human.

IARC – International Agency for Research on Cancer.

Incompatible – Materials that could cause dangerous reactions by direct contact with one another.

LACSD – Los Angeles County Sanitation District

Nanomaterial – Materials consisting of particles approximately 1 to 100 nanometers in diameter.

NIOSH – National Institute for Occupational Safety and Health, US Public Health Service, US Department of Health and Human Services (DHHS), which among other activities, tests and certifies respiratory protective devices and air sampling detector tubes, recommends occupational exposure limits for various substances, and assists OSHA and MSHA in occupational safety and health investigations and research.

OSHA – Occupational Safety and Health Administration, US Department of Labor. Sometimes referred to as Fed OSHA or Federal OSHA to distinguish it from Cal/OSHA.

Particularly Hazardous Substance (as defined in 8 CCR 5191) – A select carcinogen, reproductive toxin or substance that has a high degree of acute toxicity (causes severe and immediate health effects from limited exposure).

PEL – Permissible Exposure Limit: an exposure limit established via OSHA's regulatory authority. It may be a time weighted average (TWA) limit or a maximum concentration exposure limit.

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

PI – Principal Investigator. The PI is a faculty member directing research in a particular laboratory.

Plans Review – The review of the plans for a new building or remodeled building that includes evaluation of compliance with various regulations and safety standards.

PPE – Personal Protective Equipment.

Reproductive Toxin – A chemical which affects the reproductive system and may produce chromosomal damage (mutation) and/or adverse effects on the fetus (teratogenesis). For purposes of this guidance, any chemical with a mutagenic or teratogenic quotation in the Registry of Toxic Effects of Chemical Substances (RTECS) shall be considered a reproductive hazard.

Respirator – Devices that will protect the wearer's respiratory system from overexposure by inhalation to airborne contaminants. Respirators (or other Respiratory protections such as SCBAs) are used when a worker must work in an area where he/she might be exposed to concentrations in excess of the permissible exposure limit.

SCBA – Self Contained Breathing Apparatus.

SDS – Safety Data Sheets.

SOP – Standard Operating Procedure.

Safety Officer – Lab member appointed by and representing the PI for safety issues in the laboratory.

Title 8 – Industrial Relations. The section of the California Code of Regulations containing the regulations enforced by Cal/OSHA.

TLV – Threshold Limit Value.

Toxic – A chemical falling within any of the following categories:

1. A chemical that has a median lethal dose (LD50) of more than 50 milligrams per kilogram, but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.
2. A chemical that has a median lethal dose (LD50) of more than 200 milligrams per kilogram but not more than 1,000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.

GENERAL HEALTH AND SAFETY PRACTICES

SP1: General Laboratory Rules

- Do not work alone without prior approval.
- Develop safe work practices and avoid careless actions or horseplay.
- Be alert to unsafe conditions and immediately notify the PI/Laboratory Supervisor of unsafe conditions.
- Become familiar with the laboratory's emergency equipment (e.g., eyewash, safety shower, and fire extinguisher).
- Adhere to the intent and procedures of the Institute's Laboratory Health and Safety Programs.

SP2: Chemical Handling

General:

- Before handling chemicals, become familiar with hazards, signs and symptoms of exposure, and precautions for preventing exposure.
- Do not underestimate hazard risks associated with chemicals or mixtures.
- If the chemical mixture toxicity is unknown, assume any chemical mixture is as toxic as its most toxic component.
- Assume substances of unknown toxicity are toxic.

Exposure Limits:

- When handling chemicals, do not exceed the Cal/OSHA Permissible Exposure Limits (PELs) or American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs).

Oral Pipetting:

- Prohibited – use mechanical pipetting aids for all pipetting procedures.

Hypodermic Needles:

- Use only if no other feasible substitution is available.

Glassware:

- Handle and store with care to avoid damage.
- Do not use broken or damaged glassware.
- Shield or wrap evacuated glass apparatus to contain chemicals and fragments should implosion occur.

Laboratory Transport:

- Place chemical containers in unbreakable outer containers (chemical carriers) for transport. If several items are needed use a cart with side rails and/or use the original shipping containers to reduce the chance of an accidental spill.
- Place contaminated materials in an impermeable, sealed primary container (plastic bag).
- Label outer containers appropriately.

Housekeeping:

- Keep work area clean and uncluttered.
- Clean up operations at the end of the day.
- See General Health and Safety Practices SP13 : Housekeeping Standards.

Decontamination of Work Surfaces/Equipment

Preventive Measures

- Protect work surfaces (e.g., bench tops, hood surfaces, and floors), as appropriate, from contamination (i.e., cover with stainless steel or plastic trays, dry absorbent plastic backed paper, or other impervious material).
- Decontaminate or dispose of contaminated items used to protect work surfaces from contamination.

Methods of Decontamination

The decontamination method selected depends on the type of material that has been spilled. SDS's and chemical reference books can provide information on the selection of an appropriate method. The method of decontamination selected must be compatible with the spilled material and the conditions in the laboratory.

Both the physical nature and toxicity of contaminants must be considered when choosing the appropriate decontamination methods. Utilizing soft-bristle brushes to wash a mild detergent solution followed by rinsing with water is the most common form of decontamination. However, the method chosen should be based on specific spill conditions. The following are the three most commonly used decontamination methods.

1. *Dilution* – The use of water to flush hazardous materials from the contaminated surface. It is the most common form of decontamination.

   Advantages
   - Readily available at most laboratory locations.
   - Will not generate toxic fumes.
   - Safe for personnel, protective gear, work surfaces, and equipment.

   Disadvantages
   - Reduces contamination, but does not change chemical makeup.
   - Complications with soluble compounds.
   - Creates large amounts of potentially hazardous waste.
   - Material must be soluble in the cleaning solution.
   - Reactions with incompatible or water reactive materials such as heavy metals.

2. *Chemical Degradation* – The altering of the chemical structure of a contaminant to make it less hazardous.

   Advantages
   - Can permanently reduce the effects of a hazardous material.
   - Can limit clean-up costs.
   - Remaining material may be non-hazardous.

   Disadvantages
   - Should not be used on personnel.
   - Requires chemical expertise.
   - May produce other types of hazardous materials.

3. *Neutralization* – The introduction of another chemical to cause a chemical reaction, resulting in a less hazardous product.

   Advantages
   - Can eliminate the original hazardous properties of a material.

- Common neutralization materials are often readily available.

Disadvantages

- Will result in some form of heat exchange, sometimes posing an additional risk.
- Decontamination reagents may be hazardous.
- May give off toxic gases.

Chemical Spill Plan

An effective spill procedure should be developed for each group. The complexity and detail of the plan will depend upon the physical characteristics and volume of the materials being handled, their potential toxicity, and the potential for release to the environment.

The Spill Response Plan should include:

- Names and telephone numbers of individuals to be contacted in the event of a spill.
- Evacuation plans for the room or building.
- Instructions for containing the spilled material, including potential releases to the environment (e.g., protect the floor drains).
- Inventory of spill control materials and personal protective equipment.
- Means for proper disposal of cleanup materials (in most cases, as hazardous waste) including contaminated tools and clothing.
- Decontamination of the area following the cleanup.

SP3: Personal Protective Equipment Guidelines

1. Always wear safety glasses and a lab coat when working with chemicals. This also applies to any work involving possible physical damage to the eyes (e.g., lasers and other equipment that emit radiation at wavelengths from the ultraviolet through the near infrared).
2. Always wear goggles when the potential of a splash from hazardous materials exists; goggles can be worn over prescription glasses.
3. Avoid the use of contact lenses in the laboratory; if they are used, inform supervisor so special precautions can be taken.
4. Use face shields when working with large volumes of hazardous materials.
5. When the possibility of chemical contamination exists, wear protective clothing (a lab coat) that resists physical and chemical hazards of minor chemical splashes and spills. Wear plastic or rubber aprons when using corrosive liquids.
6. Loose clothing (such as ties or oversized lab coats), skimpy clothing (such as shorts), torn clothing, or unrestrained hair poses a hazard in the laboratory.
7. When working with corrosive, allergenic, sensitizing, or toxic chemicals, wear gloves made of material known to be resistant to permeation by the chemical.
8. Do not wear sandals, open-toed shoes, or perforated shoes in the laboratory.
9. Use a fume hood whenever exposure by inhalation is likely to exceed the threshold limits described in the SDS.
10. Consult with your supervisor when there are any changes or new procedures.
11. Inspect all protective equipment before using. Do not use defective personal protective equipment.

SP4: Hygiene Practices

Personal Hygiene

- Keep hand away from mouth, nose, eyes, and face.

- Confine long hair and loose clothing.
- Wear only non-absorbent, closed-toe shoes.

Work Practices

- Do not eat, drink, smoke, chew gum or tobacco, or apply cosmetics in the lab.
- Do not smell or taste chemicals.

Decontamination

- Wash areas of exposed skin before leaving the laboratory.
- Hand washing facilities are available within the work area, but not necessarily used exclusively for hand washing.
- Use liquid soap, whenever possible.

SP5: Eyewash and Safety Shower

- Ensure properly functioning eyewash and safety shower are accessible within 10 seconds to all employees who handle hazardous chemicals.
- Keep the area around the eyewash and safety shower clear at all times.
- The Plumbing Shop performs monthly tests on eyewashes and safety showers in accordance with the section titled “Engineering Controls Criteria and Verification.”

SP6: Chemical Storage

- Store stock quantities of hazardous chemicals in a secured area.
- Keep working quantities of chemicals to a minimum.
- Maintain quantities of chemicals stored to a minimum.
- Maintain quantities to less than the amounts required for use in one week, except amounts stored in a specific chemical storage area or cabinet that is located within the laboratory work area.
- Store flammable liquids in excess of 10 gallons in approved flammable liquid storage cabinets.
- Storage of flammable liquids outside of a cabinet should be in an approved flammable liquid container or in its original DOT approved container with secondary containment.
- Segregate reactive chemicals from incompatible chemicals (See Table 2: Segregation of Incompatible Substances).
- Affix appropriate labels to storage containers.

SP7: Use of Laboratory Fume Hoods

A laboratory fume hood is the primary control that protects users and building occupants from hazardous materials. The laboratory fume hood encloses an operation by providing a physical barrier between the user and other room occupants from hazardous gases and vapors, as well as providing protection from a possible chemical spill, release, or explosion.

- Prior to using a fume hood, become familiar with the location of the nearest exit, emergency shower, eyewash, and fire extinguisher. Make sure the pathways to these areas are unobstructed.
- The hood is not a substitute for personal protective equipment. Wear a lab coat, gloves, and safety glasses.
- Know the toxic properties of the chemical with which you work. Be able to identify signs and symptoms of over-exposure.
- Verify that the exhaust system is operating properly before working in the hood. Check the date on the certification. Only use the hood if it is current, (i.e., certified within the last year). Only use the hood when the fume hood gauge indicates the hood is operating.

- The sash is also designated for use as a safety shield in case of a spill. Adjust the sash at or below the point indicated on the certification. Use an appropriate shield if there is a chance of an explosion or eruption. Keep the sash clean and clear.
- Keep the sash completely lowered anytime there is no "hands-on" part of the experiment in progress or whenever the hood is on and unattended.
- Keep head out of hood.
- Avoid rapid movements at the hood face when the sash is open because it may create sufficient turbulence to disrupt the face velocity and cause contaminants to enter the room.
- Keep laboratory doors closed (unless laboratory's design required the lab doors to be open).
- Do not place waste into the hood for evaporation. Waste chemicals shall be accumulated for disposal, not evaporated in the hood.
- Do not place containers or equipment near the hood exhaust. Blocking the exhaust may reduce airflow to unacceptable levels and/or cause turbulence.
- Visually inspect baffles (openings at the top and rear of the hood) to be sure slots are open and unobstructed.
- Raise hot plates, ovens, and other bulky apparatus one to two inches above the work surface to allow air to flow underneath them.
- Keep all apparatus at least 6 inches behind the face and from the rear of the hood. A stripe on the bench surface is a good reminder.
- Do not store chemicals, apparatus, or containers in the hood. Store hazardous chemicals and hazardous waste in an approved safety cabinet. Materials stored in a hood disturb the air flow pattern (especially when blocking baffles) and reduce available working space.
- Avoid high velocities and cross-drafts because they may increase contamination and dust loading.
- The volume of air withdrawn from the hood must be greater than the volume of contaminated gases, fumes, or dusts created in the hood.
- All electrical devices should be connected outside the hood to avoid sparks that may ignite a flammable or explosive chemical.
- Clean all chemical residues in the hood after each use.
- Do not use a fume hood for any function which it is not intended. Certain chemicals or reactions require special constructed hoods. Examples are perchloric acid or high pressure reactions.

SP8: Compressed Gas Cylinders

- Make sure that the correct regulator and CGA connector is being used. See Table 4: CGA Connection Chart.
- Secure cylinders at the top and bottom. Keep cylinders capped when not in use.
- Cylinders should not be dropped, struck, or permitted to strike each other.
- Adjust the racks so that cylinders can be tightly secured.
- Do not expose cylinders to temperatures greater than 50° C (122° F).
- Do not lubricate, modify, force, or tamper with cylinder valves.
- Use only the correct fittings and connections to ensure compatibility.
- Use pressure regulators that are equipped with pressure relief devices, if needed.
- Avoid rapid release of compressed gases that can cause the hose to whip dangerously and/or build up a static charge that could ignite a combustible gas.
- Segregate gas cylinder storage from chemical storage.
- Keep incompatible classes of gases stored separately.
- Keep flammables from reactives which include oxidizers and corrosives.
- Always label cylinders so you know their contents; do not depend on the manufacturers' color code.

- When cylinders are no longer in use, shut the valves, relieve the pressure in the gas regulators, remove the regulators, and cap the cylinders.
- Leave a small amount of contents in the cylinder to avoid contamination.
- Segregate empty cylinders from full cylinders.
- Wear safety glasses when handling compressed gases.
- Gas cylinders including lecture bottles should be stored in an upright manner.
- Toxic gases must be stored and used in a vented cabinet or compartment with an approved fire sprinkler system.
- Caustic gases should be stored and used in a vented cabinet or compartment.
- Corrosive gases should be disposed of as hazardous waste when not in use. Manufacturers recommend removal no later than one year after use.
- Leaking regulators, cylinder valves, hose, piping systems, apparatus, and fittings shall not be used.
- For further information please see the Compressed Gas Safety Guide and Checklist.

SP9: New Procedures and Planning an Experiment

Important factors in planning and evaluating an experiment

- Evaluate new hazardous procedures with PI/Lab Supervisor and the group Safety Officer
- Evaluate the properties of the chemicals to be used
- Physical properties
- Reactivity
- Flammability
- Radiation
- Toxicity
- Biological and health effects
- Chemical products of the experiment

Select the appropriate engineering controls

- Fume hoods
- Shielding
- Glove boxes
- Vacuum lines
- Any special equipment unique to the experiment

Select the appropriate personal protective equipment based on the chemical properties evaluation

- Safety glasses
- Lab coats
- Aprons
- Face protection
- Shielding
- Gloves

Perform administrative controls

- Review the experiment with the laboratory supervisor
- Inform the group of any special hazards

SP10: Medical Surveillance

GUIDANCE ON MEDICAL SURVEILLANCE FOR LABORATORY PERSONNEL POTENTIALLY EXPOSED TO HAZARDOUS CHEMICALS

Purpose of Medical Surveillance

The purpose of a medical surveillance program is to monitor the health of employees who may be exposed to certain categories of hazardous substances or activities.

When Provided

Cal/OSHA standards trigger medical surveillance procedures if an employee is exposed to a certain action level of certain chemicals for a specific frequency of time. Laboratory-scale operations conducted in research labs rarely trigger medical surveillance.

Payment for Medical Surveillance

Caltech covers the cost of occupationally-related medical surveillance for employees.

Providers of Medical Surveillance

Licensed Physicians at

- Pasadena Saint George's Medical Clinic or
- Pasadena Community Urgent Care

Recordkeeping of Medical Information

- Pasadena Saint George's Medical Clinic or
- Pasadena Community Urgent Care

How to Obtain a Medical Exam

- ***Routine Medical Surveillance***
    - o EHS Assessment:
        - Contact EHS at 6727 for an evaluation of the chemical operation.
        - Depending on the assessment (e.g. type, quantity, frequency of chemical used, use of engineering controls, PPE, etc.), the EHS staff may conduct one or more of the following types of monitoring:
            - personal
            - general area of process
            - surface
    - o Scheduling the Medical Exam:
        - If EHS evaluation reveals the need for medical surveillance, the employee must schedule an appointment with Pasadena Community Urgent Care or Saint George's Medical Clinic.
- ***Emergencies***
    - o Initial Treatment of Exposed Employee
        - In the event of an employee's skin or eye contact with a hazardous chemical (potential overexposure), follow appropriate emergency treatment (e.g., flushing skin/eyes in eyewash safety shower, removing contaminated clothing) and call Campus emergency extension 5000.

SP11: Hazardous Waste Guidelines

- Fume hoods and drains are not to be used as waste disposal devices.
- Prepare chemical wastes for disposal according to specific waste-reduction procedures that the principal investigator has provided.
- Do not purchase more of a chemical than you expect to use in the foreseeable future. The cost of disposal often exceeds the purchase price of the chemical.
- Hazardous waste containers must be completely labeled and dated when the first drop of hazardous waste goes in.
- Use only authorized Institute Hazardous Waste Identification Tags for container labeling. Other forms of hazardous-waste identification are not acceptable. See the Environment, Health, & Safety website for more information: www.safety.caltech.edu.
- Waste containers must be kept closed except when adding hazardous waste.
- Do not fill a waste container completely to the top. Provide room for air space.
- Avoid sealing a waste container when it is colder than room temperature. Allow the waste to equilibrate to ambient temperature to prevent undue pressure buildup.
- Do not place incompatible chemicals in a waste container.
- EHS must receive all hazardous waste containers within nine (9) months from the date of initial accumulation.
- Dispose of your waste at the completion of a project. Do not abandon the waste so that someone else must deal with it.
- Arrangements for chemical analysis of unknowns can be made through EHS. Costs associated with improper handling of waste are charged back to the research group.

SP12: Working with Cryogenics

Cryogenic fluids are characterized by having a boiling point of less than -73 degrees C (-100 degree F). The boiling points of carbon dioxide and nitrogen are -78.5 degrees C and -195.8 degrees C, respectively. Another physical property of cryogenic fluids is the high-volume-expansion ratio in the liquid-to-gas phase. This ratio is 553 to 1 for carbon dioxide and 696 to 1 for nitrogen.

Improper use of cryogenic fluids may produce physical and personal hazards that are not always obvious. The primary hazard to people is skin or eye contact with splashing liquid as it warms and expands. Injuries similar to a burn will result. Safety goggles or a face shield should be worn. Clean, insulated gloves that can be easily removed are recommended. Arm and leg protection is also recommended.

All cryogenic fluids are capable of causing asphyxiation without warning by displacing oxygen-containing air. Areas where they are used or stored should be adequately ventilated.

Cryogenic fluids are capable of condensing oxygen from the air, causing oxygen enrichment resulting in increased flammability. Condensed oxygen can also react violently in the presence of organic materials and cause an explosion.

Liquefied gases are generally stored at atmospheric pressure in an insulated container, which keeps them near their boiling point, with some gas present. The large expansion in volume that takes place when the liquid becomes a gas means that pressure can build up in an unvented or unrelieved container and in transfer lines and piping. System design and maintenance must take this expansion ratio into account. Only containers designed for cryogenic fluids should be used.

The selection of materials to be used with cryogenics is important because of the changes in physical properties of materials at very low temperatures. Some materials become extremely brittle. Chemical interactions between the cryogenic liquid and its container or equipment must also be evaluated.

The Dewar flask is the most common container used for the storage and transfer of cryogenic fluids. When using the Dewar, follow these procedures:

- Cover the Dewar with a cap that allows escape of built-up pressure and keeps air and moisture out.
- Transfer cryogenic liquids from large Dewar vessels with special transfer tubes designed for the particular application.
- Tipping or tilting to pour the liquid may damage large Dewars.
- Do not use heat guns or similar equipment to warm transfer tubing quickly for disconnection.
- Handle containers carefully to protect the vacuum insulation system of Dewars.
- Place large Dewars on dollies that move freely so there is no possibility of personal injury or damage to the supported Dewars.
- Due to extremely cold temperatures of cryogenic liquids and "boil-off" gases, use the following personal protective equipment (PPE):
    - When cryogenics are present, safety glasses with side shields.
    - When cryogenics are poured or transferred,
        - Safety glasses and a full face shield.
        - Loose-fitting thermal gloves.
        - Long-sleeved clothing (lab coat).
        - Long pants.
        - Closed-toe shoes.

Anyone using cryogenic material must receive instruction in using cryogenic materials safely from their Lab Supervisor or Safety Officer.

If there is a cryogenic spill, immediately leave the area. If you believe the cryogen has caused significant oxygen depletion, do not re-enter the area unless the oxygen content of the atmosphere is at least 19.5% and there is no flammable or toxic mixture present.

SP13: Hot Plate Safety

Factors which contribute to fires associated with usage of hot plates include:

- Improper use of equipment.
- Unattended reactions.
- Poor housekeeping practices in fume hoods.

1. Equipment

- Use a temperature control unit or a thermometer to monitor the temperature. Do not use mercury thermometers – instead use an alcohol thermometer.
- Periodically check the hot plate temperature controls using a water bath and thermometer. Replace unreliable or malfunctioning equipment.
- Use water baths for temperatures up to 70-80 °C. Use silicon oil baths at temperatures of 80-200 °C. For temperatures above 200 °C, use a wood melt pot (amalgam) or sand.
- Use only heat resistant, borosilicate glassware, and check for cracks before heating on a hot plate. Do not place thick-walled glassware, such as filter flasks, or soft-glass bottles and jars on a hot plate.
- Do not heat a mixture to dryness – the glass may crack unexpectedly.

- Be careful when removing hot glassware or pouring hot liquids from a hot plate. Use gripping devices such as tongs or silicone rubber heat protectors.
- Use a medium high setting of the hot plate to heat most liquids, including water. Do not use a high setting to heat low boiling point liquids.
- Place magnetic or mechanical stir bars in liquids being heated to facilitate even heating and boiling.

2. Unattended reactions

- Do not leave a standard hot plate unattended.
- If a reaction must be left unattended, use a hot plate with overshoot protection.
- Periodically check the bath temperature.

3. Housekeeping

- Maintain a three-inch clearance of any materials from a hot plate.
- Remove any flammable or combustible materials from the fume hood when using the hot plate.
- Keep the fume hood and work area clutter free.

SP14: Housekeeping Standard

Each laboratory worker is directly responsible for the cleanliness of his or her work space, and jointly responsible for common areas of the laboratory. The Principal Investigator is responsible for the maintenance of housekeeping standards.

The following procedures apply to the housekeeping standards of the laboratory:

- **All spills on lab benches or floors shall be immediately cleaned and properly disposed of.**
    - Keep work areas free of visible contamination.
    - Keep laboratory-specific emergency signs current, including after-hours contact telephone numbers and hazard inventory.

- **The lab benches and fume hoods shall be kept clear of equipment and chemicals except those necessary for the work currently being performed.**
    - Keep work areas clean and free from obstruction.
    - Make a clear demarcation between “wet” and “dry” areas, where paperwork is done.
    - The work area shall be cleaned at the end of each operation and on a regular basis.
    - Remove clutter from fume hoods when running chemical reactions.
    - All apparatus shall be thoroughly cleaned and returned to storage upon completion of usage.
    - Place all chemicals in a proper storage area by the end of each workday.

- **All floors, aisles, exits, fire extinguishing equipment, eyewash stations, and showers, electrical disconnects, and other emergency equipment shall remain unobstructed.**
    - Do not leave solvent containers on the floor.
    - Remove excess cardboard boxes, Styrofoam, or any other combustibles from the lab.
    - Doors should not be blocked with any items.

- **Chemical containers shall be clean, properly labeled and returned to storage upon completion of usage.**
    - Use secondary containment (spill trays).

- Keep chemicals in properly sealed containers and labeled properly.
- Do not leave unlabeled chemicals in a fume hood or on a bench top.
- Place all laboratory sharps in appropriate containers, never into regular trash containers.
- Flammables must be stored in flammable liquid cabinets.

- **All chemical wastes will be disposed of in accordance with the Caltech Hazardous Waste Management Reference Guide.**

  - Keep wastes in properly sealed containers and labeled properly.
  - Place all laboratory sharps in appropriate containers, never into regular trash containers.

- **Special housekeeping measures not covered by the standard may be necessary.**

SP15: Cal/OSHA Regulated Carcinogens

This section discusses additional requirements that shall be observed for laboratories which handle Cal/OSHA Regulated Chemical Carcinogens.

Cal/OSHA Regulated Chemical Carcinogens Table

Regulated Carcinogen	Regulation 8 CCR	Regulated Carcinogen	Regulation 8 CCR
2-Acetylaminofluorene	5209	4-Dimethylaminoazobenzene	5209
Acrylonitrile	5213	Ethylene Dibromide (EDB)	5219
4-Aminodiphenyl	5209	Ethylene Oxide	5220
Arsenic, Inorganic	5214	Ethyleneimine	5209
Asbestos	1529, 5208, 8358	Formaldehyde	5217
Benzene	5218	4, 4-Methylenebis (2-Chloroanile) (MBOCA)	5215
Benzidine and its salts	5209	Methylene Chloride	5202
1, 3 Butadiene	5201	Methylenedianiline (MDA)	1535, 5200
Cadmium	1532, 5207	Alpha-Naphthylamine	5209
Bis-Chloromethyl ether	5209	Beta-Naphthylamine	5209
Methyl chloromethyl ether	5209	4-Nitrobiphenyl	5209
Coke Oven Emissions	5211	N-Nitrosodimethylamine	5209
1, 2-Dibromo-3-Chloropropane (DBCP)	5212	Beta-propiolacetone	5209
3, 3'-Dichlorobenzidine and its salts	5209	Vinyl Chloride	5210

Responsibilities

The use of Cal/OSHA Regulated Chemical Carcinogens requires additional responsibilities beyond those outlined in other sections of the Plan. Cal/OSHA requirements specific to a regulated carcinogen (8CCR) can be found at www.dir.ca.gov/samples/search/query.htm.

EHS will be responsible for:

- Registering with the Division of Occupational Safety and Health (DOSH) when regulated carcinogens are used at Caltech.
- Maintaining a current inventory of Cal/OSHA Regulated Chemical Carcinogens.

- Investigating all reported accidents which result in the exposure of personnel or the environment to a Cal/OSHA Regulated Chemical Carcinogen and recommending corrective action to reduce the potential for recurrence.

Notification of Emergencies:

- In an uncontrolled or an exposure incident of any regulated carcinogens, EHS must be immediately notified.

TABLES

TABLE 1: Select Carcinogens, Reproductive Toxins, and Compounds with a High Degree of Acute Toxicity

Carcinogens

Carcinogens are chemical or physical agents that cause cancer. Generally, they are chronically toxic substances.

*Select carcinogens are classified as "Particularly Hazardous Substances" and must be handled in a designated area.

*Classes of Carcinogenic Substances (*Select)*

Alkylating Agents

- α-Halo ethers
  - *Bis(chloromethyl) ether
  - *Methyl chloromethyl ether
- Sulfonates
  - *1,4-Butanediol dimethylsulfonate (myleran)
  - Diethyl sulfate
  - Dimethyl sulfate
  - Ethyl methanesulfonate
  - Methyl trifluoromethanesulfonate
  - 1,3-Propanesultone
- Epoxides
  - *Ethylene oxide
  - Diepoxybutane
  - Epichlorohydrin
  - Propylene oxide
  - Styrene oxide
- Azridines
  - *Ethylenimine
  - 2-methylaziridine
- Diazo, azo, and azoxy compounds
  - 4-methylaminoazobenzene
- Electrophylic alkenes and alkynes
  - *Acrylonitrile
  - Acrolein
  - Ethyl acrylate

Acylating Agents

- β-Propiolactone
- β-Butyrolactone
- Dimethylcarbamyl chloride

Organohalogen Compounds

- *1, 2-Dibromo-3-chloropropane
- *Mustard gas (bis (2-chloroethyl) sulfide)
- *Vinyl chloride
- Carbon tetrachloride
- Chloroform
- 3-Chloro-2-methylpropene
- 1,2-Dibromoethane
- 1,4-Dichlorobenzene
- 1,2-Dichloroethane
- 2,2-Dichloroethane
- 1,3-Dichloropropene
- Hexachlorobenzene
- Methyl iodide
- Tetrachloroethylene
- Trichloroethylene
- 2,4,6-Trichlorophenol

Hydrazines

- Hydrazine (and hydrazine salts)
- 1,2-Diethyl hydrazine
- 1,1-Dimethyl hydrazine
- 1,2-Dimethyl hydrazine

***N*-Nitroso Compounds**

- **N*-Nitrosodimethylamine
- *N*-Nitroso-*N*-alkyureas

Aromatic Amines

*4-Aminobiphenyl
*Benzidine (4,4'-diaminobiphenyl)
α-Napthylamine
β-Napthylamine
Aniline
o-Anisidine (2-methoxyaniline)
2,4-Diaminotoluene
o-Toluidine

Aromatic Hydrocarbons

*Benzene
Benz[*a*]anthracene
Benzo[*a*]pyrene

Natural Products (including antitumor drugs)

Adiramycin
Aflatoxins
Bleomycin
Cisplatin
Progesterone
Reserpine
Safrole

Miscellaneous Organic Compounds

*Formaldehyde (gas)
Acetaldehyde
1,4-Dioxane
Urethane (ethyl carbamate)
Hexamethylphosphoramide
2-Nitropropane
Styrene
Thiourea
Thioacetamide

Miscellaneous inorganic compounds

*Arsenic and certain arsenic compounds
*Chromium and certain chromium compounds
Thorium dioxide
Beryllium and certain beryllium compounds
Cadmium and certain cadmium compounds
Lead and certain lead compounds
Nickel and certain nickel compounds
Selenium sulfide

Reference: *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*; National Academy Press, Washington, D.C., 1995

Reproductive Toxins

Reproductive toxins include substances which cause chromosomal damage (mutagens) and substances with lethal or tetratogenic (malformation) effects on fetuses. Many reproductive toxins are chronic toxins that cause damage after repeated or long-duration exposures with effects that become evident only after long latency periods.

The following Table lists some materials that are highly suspected to be reproductive toxins.

Partial List of Reproductive Toxins

Acrylic acid	Diphenylamine	Nitrobenzene
Aniline	Estradiol	Nitrous oxide
Benzene	Formaldehyde	Phenol
Cadmium	Formamide	Polychlorinated biphenyls
Carbon sulfide	Hexachlorobenzene	Polybrominated biphenyls
N,N dimethylacetamide	Iodoacetic acid	Toluene
Dimethylformamide (DMF)	Lead compounds	Vinyl chloride
Dimetylsulfoxide (DMSO)	Mercury compounds	Xylene

The above list is not complete. It is the responsibility of the researcher to identify each compound involved in his/her work.

Acute Toxins

Acute toxicity is the ability of a chemical to cause a harmful effect after a single exposure. Acutely toxic agents can cause local toxic effects, systemic toxic effects, or both. This class of toxicants includes corrosive chemicals, irritants, and allergens (sensitizers).

Partial List of Compounds with a High Degree of Acute Toxicity

Acrylic acid
Acrylonitrile
Allylalcohol
Allylamine
Arrolein
Bromine
Chlorine
Cyanide salts
Diazomethane
Diborane (gas)
1,2-dibromethane
Dimethyl sulfate
Ethylene oxide
Hydrazine
Hydrogen cyanide
Hydrogen fluoride
Hydrogen sulfide
Methyl fluorosulfonate
Methyl iodide
Nickel carbonyl
Nitrogen dioxide
Osmium tetroxide
Ozone
Phosgene
Sodium azide

The above list is not complete. It is the responsibility of the researcher to identify each compound involved in his/her work.

TABLE 2: Segregation of Incompatible Substances

When transporting, storing, using, or disposing of any substance, exercise utmost care to ensure that the substance cannot accidentally come in contact with another with which it is incompatible. Such contact can result in an 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	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	Water, carbon tetrachloride or other chlorinated hydrocarbons, i.e., powdered aluminum or magnesium, carbon dioxide, halogens, calcium, lithium, sodium, potassium
Ammonia (anhydrous)	Mercury, chlorine, calcium hypochlorite, iodine, bromine, anhydrous HF
Ammonium nitrate	Acids, powdered metals, flammable liquids, chlorates, nitrites, sulfur, finely divided organics or combustibles
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent
Bromine	See Chlorine
Calcium Oxide	Water
Carbon (activated)	Calcium hyperchlorite, 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)	Fluorine, chlorine, bromine, chromic acid, sodium peroxide

Chemical	Incompatible with
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
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, brass, any heavy metals
Nitrates	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 (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

TABLE 3: Chemical Resistance Chart

Explanation of Ratings

Breakthrough detection times (BDT) are given in minutes. Chemical Protective Clothing (CPC) index ratings are based on the Forsberg system, which relies on both breakthrough times and permeation rates to establish a rating system for chemical protective clothing. The ratings range from 0 to 5, with 0 being the best and 5 being the worst.

Chemical Protective Clothing Performance Index Rating (CPC)

0 Best selection for unlimited exposure. No breakthrough.
1 Next best selection for unlimited exposure.
2 Sometimes satisfactory. Good for limited exposure.
3 Poor choice. Not for heavy exposure.
4 Very poor choice. For splashes only.
5 Not recommended.

Chemical by Class	Neoprene		Nitrile		Rubber		PVC		Butyl		Viton	
	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC
Aliphatic Solvents												
1. Cyclohexane	21	2	9	0	55	5	13	3	ND	4	NR	0
2. Gasoline/Unleaded	46	3	46	0	NR	5	22	3	NR	5	ND	0
3. Heptane	ND	0	ND	0	24	3	39	4	23	4	ND	0
4. Hexane	173	2	234	0	21	4	29	3	13	5	ND	0
5. Isooctane	ND	0	ND	0	57	3	114	3	56	4	ND	0
6. Kerosene	ND	0	ND	0	NR	5	ND	0	94	4	ND	0
7. Petroleum Ether	99	2	ND	0	5	5	19	4	15	4	ND	0
Acids, Organic												
8. Acetic 84%	ND	0	240	5	ND	0	300	2	ND	0	ND	0
9. Formic 90%	ND	0	75	0	ND	0	ND	0	ND	0	120	0
Acids, Mineral												
10. Battery 47%	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
11. Hydrochloric 37%	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
12. Hydrofluoric 48%	ND	0	60	3	45	3	110	2	ND	0	185	1
13. Muriatic 10%	ND	0	ND	0	ND	0	ND	4	ND	0	ND	0
14. Nitric 70%	ND	0	NR	5	ND	0	240	5	ND	0	ND	0
15. Sulfuric 97%	ND	0	180	3	ND	0	210	5	ND	0	ND	0
Alcohols												
16. Amyl	ND	0	ND	0	ND	0	116	2	ND	0	ND	0
17. Butyl	ND	0	ND	0	ND	0	155	2	ND	0	ND	0
18. Cresols	ND	0	NR	5	371	2	ND	0	ND	0	ND	0
19. Ethyl	ND	0	225	4	ND	0	66	2	ND	0	ND	0
20. Methyl	226	1	28	3	82	2	39	4	ND	0	ND	0
21. Isobutyl	ND	0	ND	0	ND	0	ND	2	ND	0	ND	0
Aldehydes												

Chemical by Class	Neoprene		Nitrile		Rubber		PVC		Butyl		Viton	
	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC
22. Acetaldehyde	21	3	NR	5	55	3	13	5	ND	0	NR	5
23. Benzaldehyde	93	3	NR	5	81	3	NR	5	ND	0	ND	0
24. Formaldehyde	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
25. Furfural	165	2	NR	5	ND	0	85	3	ND	0	298	3
Alkalis												
26. Ammonium Hydroxide	ND	0	240	3	120	3	60	4	ND	0	ND	0
27. Potassium Hydroxide	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
28. Sodium Hydroxide	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
Amides												
29. Dimethylacetamide	84	3	NR	5	29	4	51	4	ND	0	NR	5
30. Dimethylformamide	100	3	NR	5	ND	0	NR	5	ND	0	NR	5
31. N-MethylPyrrolidone	ND	0	34	3	ND	0	140	4	ND	0	NR	5
Amines												
32. Aniline	32	3	NR	5	1	4	71	3	ND	0	ND	0
33. Butylamine	NR	5	NR	5	45	3	15	3	45	3	NR	5
34. Diethylamine	23	5	60	5	60	5	107	4	30	3	9	5
Aromatic Solvents												
35. Benzene	15	5	16	4	NR	5	13	5	34	4	ND	0
36. Toluene	25	4	26	4	NR	5	19	4	22	4	ND	0
37. Xylene	37	4	41	4	NR	5	23	3	NR	5	ND	0
Chlorinated Solvents												
38. Carbon Tetrachloride	73	4	ND	0	NR	5	46	4	53	4	ND	0
39. Chloroform	23	4	6	5	NR	5	10	5	21	4	ND	0
40. Methylene Chloride	NR	5	4	5	NR	5	NR	5	20	4	113	3
41. Perchloroethylene	40	4	ND	0	NR	5	NR	5	28	4	ND	0
42. Trichloroethylene	12	5	9	5	NR	5	NR	5	13	5	ND	0
43.1,1,1Trichloroethane	51	4	49	4	NR	5	52	3	72	4	ND	0
Esters												
44. Amyl Acetate	110	3	77	4	NR	5	NR	5	158	3	NR	5
45. Ethyl Acetate	24	4	30	4	72	4	5	5	212	2	NR	5
46. Methyl Methacrylate	27	3	NR	5	77	3	NR	5	63	3	NR	5
Ethers												
47. Cellosolve Acetate	228	3	47	4	107	3	64	4	ND	0	NR	5
48. Ethyl Ether	12	5	33	4	11	5	14	5	19	5	29	5
49. Tetrahydrofuran	13	5	5	5	NR	5	NR	5	24	4	NR	5
Gases												
50. Ammonia, Anhydrous	29	2	336	1	4	4	19	3	ND	0	ND	0
51. 1,3-Butadiene	33	3	ND	0	25	3	24	3	473	2	ND	0
52. Chlorine	ND	0	ND	0	ND	0	360	2	ND	0	ND	0

Chemical by Class	Neoprene		Nitrile		Rubber		PVC		Butyl		Viton	
	BDT	**CPC**	**BDT**	**CPC**	**BDT**	**CPC**	**BDT**	**CPC**	**BDT**	**CPC**	**BDT**	**CPC**
53. Ethylene Oxide	21	4	17	5	1	5	1	5	189	2	48	4
54. Hydrogen Fluoride	210	2	1	5	142	1	1	5	ND	0	6	3
55. Methyl Chloride	84	1	ND	0	52	2	ND	0	ND	0	ND	0
56. Vinyl Chloride	7	4	ND	0	2	4	19	3	268	1	ND	0
Ketones												
57. Acetone	35	3	3	5	9	5	7	5	ND	0	NR	5
58. Methyl Ethyl Ketone	30	3	NR	5	12	5	NR	5	202	2	NR	5
59. MIBK	41	3	5	5	38	4	NR	5	292	2	NR	5
Nitriles												
60. Acetonitrile	65	3	6	5	16	3	24	4	ND	0	NR	5
61. Acrylonitrile	27	3	NR	5	48	3	14	5	ND	0	55	4

Reference: Forsberg and Keith (1989) Chemical Protective Clothing Performance Index Book. John Wiley and Sons.

TABLE 4: CGA Connection Chart

CYLINDER GAS TYPE	CHEMICAL SYMBOL	CGA CONNECTION Standard/Alternate
Acetylene	C_2H_2	510/300
Air	----	590/346
Allene	CH_2:C:CH_2	510
Ammonia Anhydrous	NH_3	240/705
Ammonia (VHP)	---	660
Antimony Penta Fluoride	SbF_5	330
Argon	Ar	580
Argon (Research Grade)	---	590
Arsine	AsH_3	350/660
Boron Trichloride	BCl_3	660/330
Boro Trifluoride	BF_3	330
Bromine Pentafluoride	BrF_5	670
Bromine Trifluoride	BrF_3	670
Bromoacetone	$BrCH_2COCH_3$	300/660
Bromochlorodifluoromethane	$CBrClF_2$	668/660
Bromochloromethane	CH_2BrCL	668/660
Bromotrifluoroethylene	Br FC:CF_2	510/660
Bromotrifluoromethane	$CBrF_3$	668/320, 660
1,3 - Butadiene	CH_2:CHCH:CH_2	510
Butane	$CH_3CH_2CH_2CH_3$	510
Butenes	CH_3CH_2CH:CH_2	510
Carbon Dioxide	CO_2	320
Carbon Monoxide	CO	350
Carbonyl Fluoride	COF_2	660/750
Carbonyl Sulfide	COS	330
Chlorine	CL_2	660
Chlorine Pentafluoride	CLF_5	670
Chlorine Trifluoride	ClF_3	670
Chlorodifluoroethane	$CH_3CCL\ F_2$	510/660
Chlorodifluoromethane	CH Cl F_2	660/668
Chlorofluoromethane	CH_2 Cl F	510
Chloroheptafluorocyclobutane	C_4F_7Cl	660/668
Chloropentafluoroethane	C_2CLF_5	668/660
Chlorotrifluoromethane	$CClF_3$	668/320,660
Cyanogen	C_2N_2	750/660
Cyanogon Chloride	CNCl	750/660
Cyclobutane	C_4H_8	510
Cyclopropane	C_3H_6	510
Deuterium	D_2	350
Deuterium Chloride	DCl	330
Deuterium Fluoride	DF	330
Deuterium Selenide	D_2 Se	350 / 330
Deuterium Sulfide	D_2S	330

CYLINDER GAS TYPE	CHEMICAL SYMBOL	CGA CONNECTION Standard/Alternate
Diborane	B_2H_6	350
Dibromodifluoroethane	$C_2H_2Br_2F_2$	668/660
Dibromodifluoromethane	CBr_2F_2	668/660
1,1 - Difluoroethylene	FCH:CHF	320
Dichlorosilane	H_2 Si Cl_2	330/510
Diethylzinc	$(C_2H_5)_2Zn$	750
Dimethylamine	$(CH_3)_2NH$	705/240
Dimethyl Ether	CH_3OCH_3	510
2,2 Dimethyl Propane	$C(CH_3)_4$	510
Diphosgene	$ClCO_2CCl_3$	750/660
Ethane	C_2H_6	350
Ethane (Research Grade)	---	350
Ethylacetylene	CH_3CH_2:CH	510
Ethylchloride	CH_3CH_2Cl	510/300
Ethyldichloroarsine	$C_2H_5AsCl_2$	750/660
Ethylene	CH_2:CH_2	350
Ethylene Oxide	C_2H_4O	510
Ethyl Ether	$(C_2H_5)_2O$	510
Ethyl Fluoride	C_2H_5F	750/660
Fluorine	F_2	679/670
“Freon 12” (Dicholordifluoromethane)	Cl_2	660
“Freon 13” (Chlorotrifluoromethane)	$CClF_3$	320
“Freon 1381” (Bromotrifluoromethane)	$CBrF_3$	320
“Freon 14” (Tetrafluoromethane)	CF_4	320
“Freon 22” (Chlorodifluoromethane)	$CHClF_2$	660/620
“Freon 114” (1,2 – Dichlorotetrafluoroethane)	Cl F_2 CCCl F_2	660
“Freon 116” (Hexafluoroethane)	C_2F_6	320
“Freon 8318” (Octafluorocyclobutane)	C_4F_8	660
“Genetron 21” (Dichlorofluoromethane)	$CHCl_2F$	660
“Genetron 23” (Fluoroform)	CH F_3	320
“Genetron 115” (Monochloropentafluoroethane)	Br F_2 CCF_3	660
“Genetron 152A” (1,1 – Difluoroethane)	F CH_2 CH_2 F	660
Germane	Ge H_4	660/750
Helium	He	580/677
Heptafluorobutyronitrile	C_4F_7N	750/660
Hexafluoracetone	C_3F_6O	660/330
Hexafluorocyclobutene	C_4F_6	750/660
Hexafluorodimethyl Peroxide	CF_3OOCF_3	755/660
Hexafluoroethane	C_2F_6	660/668
Hexafluoropropylene	CF_3CF:CF_2	668/660
Hydrogen	H_2	350
Hydrogen Bromide	HBr	330
Hydrogen Chloride	HCL	330
Hydrogen Cyanide	HCN	750/160
Hydrogen Fluoride	HF	330/660

CYLINDER GAS TYPE	CHEMICAL SYMBOL	CGA CONNECTION Standard/Alternate
Hydrogen Iodide	HI	330/660
Hydrogen Selenide	H_2Se	350/660
Hydrogen Sulfide	H_2S	330
Iodine Pentafluoride	IF_5	670
Isobutane	C_4H_{10}	510
Isobutylene	C_4H_8	510
Krypton (research Grade)	Kr	590
“Manufactured Gas B”	---	350
“Manufactured Gas C”	---	350
Lewsite	$ClCH:CHAsCL_2$	750/660
Methane	CH_4	350
Methylacetylene	$CH_3C:CH$	510
Methyl Bromide	CH BR	320/660
3-Methyl – 1 -butene	$(CH_3)_2CHCH:CH_2$	510
Methyl Chloride	CH_3Cl	660/510
Methyldichloroarsine	CH_3AsCl_2	750
Methylene Fluoride	CH_2F_2	320
Methyl Ethyl Ether	$CH_3OC_2H_5$	510
Methyl Fluoride	CH_3F	350
Methyl Formate	$HCOOCH_3$	510/660
Methyl Mercaptan	CH_3SH	330/750
Monoethylamine	$CH_3CH_2NH_2$	240/705
Monomethylamine	CH_3NH_2	240/705
Mustard Gas	$S(C_2H_4Cl)_2$	750/350
Natural Gas	---	350/677
Neon	Ne	590/580
Nickel Carbonyl	$Ni\ (CO)_4$	320/750
Nitric Oxide	NO	660/755, 160
Nitrogen	N_2	580
Nitrogen (Research Grade)	---	590
Nitrogen Dioxide	NO_2	660/160
Nitorgen Trifluoride	NF_3	679
Nitrogen Trioxide	N_2O_3	660/160
Nitrosyl Chloride	NOCl	660/330
Nitrosyl Fluoride	NOF	330
Nitrous Oxide	N_2O	326
Nitryl Fluoride	NO_2F	330
Octafluorocyclobutane	C_4F_8	660/668
Octafluoropropane	C_3F_8	660/668
Oxygen	O_2	540
Oxygen Difluoride	OF_2	679
Ozone	O_3	660/755
Pentaborane	B_5H_9	660/750
Pentachlorofluoroethane	CCl_3CCl_2F	668/660
Pentafluoroethyl Iodine	CF_3CF_2I	668/660

CYLINDER GAS TYPE	CHEMICAL SYMBOL	CGA CONNECTION Standard/Alternate
Pentafluoropropionitrile	CF_3CF_2CN	750/660
Perchloryl Fluoride	ClO_3F	670
Perfluorobutane	C_4F_{10}	668
Perfluorobutene – 2	C_4F_8	660
Phenylcarbylamine Chloride	$C_6H_5N : CCl_2$	330/660
Phosgene	$COCl_2$	660
Phosphine	PH_3	660/350
Perfluoropropane	---	660
Phosphorous Pentafluoride	PF_5	330
Phosphorous Trifluoride	PF_3	330
Propane	C_3H_8	510
Propylene	C_3H_6	510
Silane	SiH_4	350/510
Silicon Tetrafluoride	SiF_4	330
Stibine	SbH_3	350
Sulfur Dioxide	SO_2	660/668
Sulfur Hexafluoride	SF_6	590/668
Sulfur Tetrafluoride	SF_4	330
Sulfuryl Fluoride	SO_2F_2	660/330
1, 1, 1, 2 – Tetrachlorodifluoroethane	$C_2Fl_4F_2$	668/660
1, 2, 2, 2, - Tetrafluorochloroethane – 1	C_2HClF_4	668/660
Tetrafluoroethylene	C_2F_4	350/660
Tetrafluorohydrazine	N_2F_4	679
Tetrafluoromethane	CF_4	580/320
Tetramethyllead	$(CH_3)_4Pb$	750/350
Trichlorofluoromethane	CCl_3F	668/660
Trichlorotrifluoroethane	CF_3CCl_3	668/660
Triethylaluminum	$(C_2H_5)_3Al$	750/350
Triethylborane	$(CH_5)_3B$	750/350
Trifluoroacetonitrile	CF_3CN	750/350
Trifluoroacetyl Chloride	CF_3COCl	330
1, 1, 1 – Trifluoroethane	CH_3CF_3	510
Trifluoroethylene	C_2F_3H	510
Trifluoromethyl Hypofluorite	CF_3OF	679
Trifluoromethyl Iodide	CF_3I	668/660
Trimethylamine	$(CH_3)_3N$	240/705
Trimethylstibine	$(CH_3)_3Sb$	750/350
Tungsten Hexafluoride	WF_6	330/679
Uranium Hexafluoride	UF_6	330
Vinyl Bromide	C_2H_3Br	320/510
Vinyl Chloride	C_2H_3Cl	290/510
Vinyl Fluoride	C_2H_3F	320/350
Vinyl Methyl Ether	$C_2H_3OCH_3$	290/510
Xenon	Xe	580/677
Xenon (Research Grade)	---	590

TABLE 5: Drain Discharge Restrictions for Laboratories:

Drain discharge is regulated by the Los Angeles County Sanitation District (LACSD). Regulations concerning sewer use are found in the LACSD Wastewater Ordinance.

Note: Sanitary sewers are distinctly different from storm drains. Storm drain effluent goes untreated directly to the ocean. Sanitary sewage is pre-treated before being re-used or discharged to the ocean.

The Sewer Use Ordinance specifically **prohibits the following** from being disposed of via sanitary sewer:

1. Very hot (>150 F 0 or very cold (< 32 F) liquids. Generally bench top quantities of very hot or very cold liquids used in laboratories can be poured down the drain since all campus liquids are mixed together and liquid temperatures will moderate before leaving campus.
2. Any gasoline, benzene, naphtha, solvent, fuel oil, or any liquid, solid, or gas that would cause or tend to cause flammable or explosive conditions in the sewerage system.
3. Liquids with a pH <5 or >9.
4. Solid or viscous material which is likely to cause obstruction to sewer flow or be detrimental to wastewater treatment. Objectionable substances include but are not limited to asphalt, mud, straw, plastics, wood, paper products, and dead animals.
5. Petroleum or mineral based oils, non-biodegradable oil, or refined petroleum products.
6. Dispersed biodegradable oil, fats and greases such as lard, tallow or vegetable oil.
7. Strongly colored solutions.
8. Cyanide and Heavy Metals.
9. Radioactive materials.
10. Mercaptans, sulfides, phenols, or any strongly odorous material or material tending to create odors.
11. Any substance promoting or causing the promotion of toxic gases.
12. Untreated infectious or biohazardous waste in accordance with the Medical Waste Act.
13. Any waste which adversely affects air quality.
14. Unknown Materials.

Glass washing and experiment preparation:

Only water-soluble chemicals that pose little or no hazard in dilute aqueous solution may be used in sinks for glass washing.

Collect wash water as hazardous waste if contaminants **exceed** the values below:

CONTAMINANT	Concentration
Cyanide	10 mg/l
Arsenic	3 mg/l
Cadmium	10 mg/l
Chromium	10 mg/l
Copper	15 mg/l
Lead	40 mg/l
Mercury	2 mg/l
Nickel	12 mg/l
Silver	5 mg/l
Zinc	25 mg/l
Total Identifiable Chlorinated Hydrocarbons (TICH)	None

For questions related to drain discharge restrictions for laboratories, please contact: Environment, Health, and Safety at (626) 395-6727 or by email: safety@caltech.edu.