California Institute of Technology

CHEMICAL HYGIENE PLAN

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CHEMICAL HYGIENE PLAN

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INTRODUCTION

The purpose of the California Institute of Technology's (Caltech's) Chemical Hygiene Plan (CHP) is to establish a written program for protecting employees from the health and safety hazards associated with exposure to potentially hazardous chemicals. This CHP provides for and supports the procedures, equipment, personal protective equipment, and work practices for protecting employees from potentially hazardous chemicals in a laboratory setting.

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.

SCOPE

Caltech's CHP applies to all Caltech employees who work in research laboratories that store, handle, or utilize potentially hazardous chemicals. This CHP provides a broad overview of the information needed for safely working with hazardous chemicals in the laboratory; however, given the varied nature of the chemical work performed in the laboratories at Caltech, this CHP is not intended to be all-inclusive.

This CHP does not cover the use of radiological materials or biological agents. Procedures and requirements for work with these materials are covered in Caltech's Radiation Safety Manual and Biosafety Manual, respectively. This CHP also does not cover the use of Select Agents, Chemical Precursors, or Controlled Substances, all of which are managed under Caltech's Office of Research Policy. Chemical hazards in non-laboratory settings are covered in the Caltech Hazard Communication Program.

ROLES & RESPONSIBILITIES

FACULTY/CORE FACILITY MANAGER

The Faculty/Core Faciltiy Manager is responsible for the health and safety of employees doing work in the laboratory.

The Faculty/Core Facility Manager must:

- Implement and apply the Chemical Hygiene Program.
- Identify hazardous conditions or operations in the lab.
- Ensure that standard operating procedures (SOPs) for the safe use of hazardous chemicals are developed, available, and followed by employees.
- Ensure employees are appropriately trained to work safely with hazardous chemicals and maintain records of lab specific training provided.
- Ensure employees have access to Safety Data Sheets (SDS) for hazardous materials used in the laboratory.
- Promptly report any problems pertaining to the operation of workplace controls (e.g., fume hoods) and safety equipment (e.g., emergency showers/eyewashes, fire extinguishers) to EH&S and/or Facilities.
- Ensure that appropriate personal protective equipment is available, functioning properly, and used as required and/or needed.

- Identify laboratory operations, procedures, and activities that require prior approval; designating the approval authority.

EMPLOYEES

All employees who work with hazardous chemicals in research laboratories must:

- Follow the CHP.
- Comply with oral and written safety rules, regulations, and standard operating procedures required for the task assigned.
- Know and understand the hazards of materials and processes prior to conducting work and utilizing appropriate measures to control these hazards.
- Attend necessary or required training.
- Evaluate, maintain, and use personal protective equipment (PPE).
- Participate in medical surveillance when required.
- Report unsafe conditions to the Faculty or immediate Supervisor.
- Keep the work areas safe and uncluttered.

ENVIRONMENTAL HEALTH AND SAFETY

EH&S, which includes a Chemical Hygiene Officer (CHO), provides technical guidance on matters pertaining to laboratory safety:

- Assists the Faculty/Supervisor with hazard assessments of the overall operation to determine the appropriate safety control requirements, including engineering controls, laboratory safety practices, training, and personal protective equipment.
- Performs industrial hygiene monitoring for evidence of personnel exposure and/or equipment contamination, as needed.
- Review chemical procedures, as needed.
- Help in determining medical surveillance requirements for personnel.
- Maintain employee exposure monitoring and medical surveillance records.
- Review plans and chemical inventories for new laboratory construction, plans for renovation, or installation of engineering controls, as needed.
- Review and evaluate the effectiveness of the CHP at least annually and update it, as necessary.
- Know and comply with applicable Federal, State, and Local regulations.
- Provide technical assistance on chemical storage, classification, compatibility, and Safety Data Sheets.
- Perform laboratory safety surveys and propose corrective actions.

GENERAL CLASSES OF HAZARDOUS CHEMICALS

Chemicals have inherent physical, chemical, and toxicological properties that require employees to have a good understanding of their related health and physical hazards. Knowing the effects of a possible exposure and the steps to take if an exposure is suspected are crucial to the overall safety in a laboratory. Classifying chemicals by hazard is also helpful in determining proper storage, handling, and disposal.

HEALTH HAZARDS

Chemicals are considered a health hazard if they are carcinogens, toxic or highly toxic, reproductive toxicants, irritants, corrosives, sensitizers, hepatotoxins (liver), nephrotoxins (kidneys), neurotoxins (nervous system), agents that act on hematopoietic systems (blood), and agents that damage the lungs, skin, eyes, or mucus membranes. The main classes of health hazard chemicals and their related health and safety risks are detailed below.

CORROSIVES

Corrosive chemicals are those that cause destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. Corrosive chemicals can be liquids, solids, or gases. Corrosive materials may corrode materials they come in contact with, such as metal, and may be highly reactive with other substances.

Personnel handling corrosives should implement controls to minimize the likelihood of contact or exposure. Symptoms of exposure by inhalation may include coughing, burning sensation, wheezing, shortness of breath, nausea, and vomiting. For eye contact, symptoms may include pain, blood shot eyes, tearing, and blurring of vision. For skin contact, symptoms may include reddening, pain, inflammation, bleeding, blistering, and burns.

Common types of corrosive substances include:

- Strong acids (nitric, hydrochloric, and sulfuric acids)
- Strong bases (potassium hydroxide and ammonium hydroxide)
- Dehydrating agents (sulfuric acid, phosphorus pentoxide, and calcium oxide)
- Oxidizing agents (chlorine, bromine, hydrogen peroxide)

IRRITANTS

Irritants cause reversible effects to living tissue by chemical action at the point of contact. While irritants are not as hazardous as corrosives, personnel handling irritants should take similar care to avoid contact. Symptoms of exposure can include reddening of skin, discomfort, and irritation to the respiratory system. Wide varieties of chemicals are irritants, including organic and inorganic chemicals, of both solids and liquids.

SENSITIZERS

Sensitizers are substances that cause hypersensitivity and an allergic response after repeated exposures. Caution to avoid initial contact by personnel handling sensitizers should be taken. Exposure to sensitizers can lead to symptoms associated with allergic reactions or can increase an individual's existing allergies. Common examples of sensitizers include phenol derivatives, latex, and formaldehyde.

PARTICULARLY HAZARDOUS SUBSTANCES

Particularly hazardous substances are chemicals with certain health hazards that pose a significant threat to human health. The three types of health hazards that qualify a chemical as being a particularly hazardous substance include select carcinogens, reproductive toxicants, and substances with a high degree of acute toxicity. Additional provisions for working with Particularly Hazardous Substances are described here**.** See Table 1 for common examples of Particularly Hazardous Substances.

SELECT CARCINOGENS are chemicals that may cause cancer, typically after repeated or chronic exposure. Their effects may only become evident after a long latency period and may cause no immediate harmful effects. The following references are used to determine chemicals that Cal/OSHA considers a select carcinogen:

- Cal/OSHA Carcinogen List: https://www.dir.ca.gov/title8/sb7g16a110.html
- Annual Report on Carcinogens by the National Toxicological Program, including all of the substances listed as "known to be carcinogens" and substances listed as "reasonably anticipated to be carcinogens": https://ntp.niEH&S.nih.gov/ntp/roc/content/listed_substances_508.pdf
- The International Agency for Research on Cancer, including all of the Group 1, 2A, and 2B chemicals: http://monographs.iarc.fr/ENG/Classification/latest_classif.php

REPRODUCTIVE TOXICANTS are chemicals that may affect the reproductive capabilities in humans, including chromosomal damage (mutations) and effects on the fetuses (teratogenesis). Examples of reproductive toxicants found in laboratories include ethidium bromide, lead, and toluene.

ACUTE TOXICANTS are chemicals that can cause immediate harm and possible death in the event of an exposure. Median lethal dose (LD_{50}) experiments in animal models are typically reported and used determine if a chemical has a high degree of acute toxicity. These tests are administered orally, dermally, and via inhalation and this information can be found in a material's Safety Data Sheet, if available. Chemicals considered as acute toxicants have at least one of the following:

- Oral LD_{50} is less than or equal to 50 mg/Kg for rats.
- Dermal LD_{50} is less than or equal to 200 mg/Kg when administered by continuous contact for 24 hours to rabbits.
- Median lethal concentration, LC_{50}, of less than or equal to 200 ppm (gas, vapor) or less than or equal to 2 mg/L (mist, dust, fume) when administered by continuous inhalation for 1 hour to rats.

Examples of acute toxicants found in laboratories include sodium cyanide, sodium azide, and hydrofluoric acid.

TOXIC CHEMICALS AND SUBSTANCES WITH TOXIC EFFECTS ON SPECIFIC ORGANS

Toxic chemicals can refer to chemicals with acute toxicity or chronic toxicity. In addition to organ-specific toxicities, toxic chemicals may also have LD_{50} (oral, dermal) or LC_{50} (inhalation) values of the following:

- Oral LD_{50} >50 mg/Kg but ≤500 mg/Kg in rats.
- Dermal LD_{50} >200 mg/Kg but ≤1000 mg/Kg in rabbits.
- Inhalation LC_{50} >200 ppm but ≤2000 ppm of gas or vapor when administered for 1 continuous hour to rats.
- Inhalation LC_{50} >2 mg/L but ≤20 mg/L of mist, fume, or dust when administered for 1 continuous hour to rats.

Toxicity may target a specific organ including substances that are hepatotoxins, nephrotoxins, neurotoxins, and hematotoxins. Symptoms of exposure to these materials vary, so personnel should review the Safety Data Sheet for the specific material being used for the associated symptoms.

PHYSICAL HAZARDS

Chemicals are considered a physical hazard if they are corrosive (see above), flammable, pyrophoric, water reactive, explosive, potentially explosive, compressed gases, cryogenics, and/or oxidizers. These classes of chemicals with physical hazards are detailed below.

FLAMMABLES

In general, a materials' flash point, the lowest temperature at which an ignition source can cause the chemical to ignite readily, determines the flammability of a chemical. Flash point information on a substance can be found in the SDS, if available. Liquids are considered flammable if they have a flash point at or below 199.4 °F (93 °C) and have a vapor pressure not exceeding 40 pounds per square inch at 100 °F (37.8 °C). There are also flammable gases and solids, and the SDS should be consulted to see if they are considered flammable. Flammables should be handled in well-ventilated areas and away from ignition sources.

PYROPHORICS

Chemicals that spontaneously ignite when exposed to air are considered pyrophoric. Pyrophoric chemicals exist as liquids (most common), solids, and gases. Pyrophoric chemicals require specialized handling techniques or additional engineering controls in order to be safely handled. In addition to specialized equipment, extensive training is required to use these materials, which is to be administered by the lab. Examples of pyrophoric chemicals are tert-butyl lithium, trimethylaluminum, silane, and methylmagnesium bromide.

WATER REACTIVES

Chemicals considered water reactive emit toxic or flammable gas when exposed to water. Often exposure of these chemicals to water also generates heat, so a fire can result. Some chemicals are so highly reactive with water that moisture in the air is sufficient to cause a violent reaction. Similar to pyrophoric chemicals, some water reactive chemicals require special handling techniques, engineering controls, and training for safe handling. Common water reactive chemicals in the laboratory include sodium, lithium, trichlorosilane, and sodium borohydride.

EXPLOSIVES AND POTENTIALLY EXPLOSIVE

The use of explosive chemicals, such as trinitrotoluene, is very uncommon in Caltech laboratories. More likely is the use of chemicals that are potentially explosive under certain conditions or chemicals that can become explosive upon decomposition, polymerization, oxidation, drying out, or some other destabilizing event. Picric acid is an example of a chemical that becomes explosive when it dries out and hence the importance of keeping it wet. Also common in research laboratories are peroxide forming chemicals, which can form explosive crystals after exposure to air. This information is typically available in their SDS.

COMPRESSED GASES AND CRYOGENICS

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. Contact with cryogenics can also cause frostbite.

OXIDIZERS

Oxidizers are chemicals that initiate or promote combustion through a chemical reaction. This chemical reaction can result in or intensify a fire, or cause an explosion. Care should be taken to prevent unintentional mixing of flammables, combustibles, or other incompatible materials with oxidizers. Common oxidizers in laboratories include pure oxygen, nitric acid, and potassium permanganate.

NANOMATERIALS

Although the use of nanomaterials in research laboratories is increasing, the health effects of nanomaterials has not been thoroughly investigated. Consequently, the uncertainty pertaining to the toxicity of these types of materials merits a cautious approach when working with them. 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. To assist researchers in planning their work with nanomaterials, the California Nanosafety Consortium of Higher Education has published a document on safe work practices, which can be found here: https://www.safety.caltech.edu/documents/14132/Nanomaterials_Toolkit.pdf

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 Faculty 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.

CHEMICALS REQUIRING APPROVAL

Any use of the chemical carcinogens listed in Title 8 - California Code of Regulations, Section 5209, see table below, **requires an assessment from EH&S prior to beginning work**. An assessment is needed because use of these chemicals requires the implementation of specific safety controls that are not covered in this CHP. Use may also require reporting to Cal/OSHA.

Prior to obtaining any of these chemicals, please contact EH&S to begin the assessment process.

Chemical Carcinogens Requiring Approval

2-Acetylaminofluorene (CAS # 53-96-3)	4-Nitrobiphenyl (CAS # 92-93-3)
4-Aminodiphenyl (CAS # 92-67-1)	N-Nitrosodimethylamine (CAS # 62-75-9)
Benzidine (and its salts) (CAS # 92-87-5)	beta-Propiolactone (CAS # 57-57-8)
3,3'-Dichlorobenzidine (and its salts) (CAS # 91-94-1)	bis-Chloromethyl ether (CAS # 542-88-1)
4-Dimethylaminoazobenzene (CAS # 60-11-7)	Methyl chloromethyl ether (CAS # 107-30-2)
alpha-Naphthylamine (CAS # 134-32-7)	Ethyleneimine (CAS #151-56-4)
beta-Naphthylamine (CAS # 91-59-8)	

CONTROLS TO REDUCE EXPOSURES TO HAZARDOUS CHEMICALS

Chemical safety is achieved by an acute awareness of chemical hazards, by understanding how to keep chemical reactions under control, and by using measures to mitigate potential exposures. The methods and controls used to reduce chemical exposure include Engineering Controls, Administrative Controls, and Personal Protective Equipment.

ENGINEERING CONTROLS

Engineering controls, such as fume hoods, are one of the most effective controls for mitigating exposure to hazardous chemicals. 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.

Fume hoods are the most common engineering control utilized at Caltech and guidance for the proper use of fume hoods is provided in SP7: Use of Laboratory Fume Hoods.

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.
- Emergency eyewash and safety showers: Shall be in accessible locations that require no more than 55 feet for the injured person to reach. The area of the eyewash and shower equipment must be kept clear of items that obstruct their use.

PERFORMANCE VERIFICATION OF ENGINEERING CONTROLS AND SAFETY 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	EH&S HVAC Shop	8 CCR 5154.1 8 CCR 5143

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

ADMINISTRATIVE CONTROLS

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

- Substitute hazardous chemicals with less hazardous alternatives (e.g. using toluene instead of benzene; using water based detergents over solvents for cleaning).
- Rigorously follow SOPs when conducting laboratory work involving hazardous chemicals.
- Follow general laboratory safety and health procedures (see General Health and Safety Practices).
- Substitute more robust equipment (e.g., using safety cans instead of glass bottles).
- Depending on the risk assessment, performing multiple small scale experiments may carry less risk than one large scale experiment. Perform experiments using the smallest chemical scale as practical.
- Isolate the operator or process.

- Critical review for laboratory activities involving particularly hazardous substances or procedures.

Additional examples of Administrative Controls, including those specific to certain types of hazardous materials, are provided in the General Health and Safety Practices section.

PERSONAL PROTECTIVE EQUIPMENT

In addition to Engineering and Administrative Controls, appropriate Personal Protective Equipment (PPE), determined by a hazard assessment, may be necessary to ensure mitigation of chemical exposure risk. Employees must be trained on the proper use and care of PPE. Consult the SDS, Faculty/Laboratory Supervisor, or EH&S to determine the correct PPE for the chemical process. See SP3: Personal Protective Equipment Guidelines.

TYPES OF PPE

The following PPE may be required in chemical laboratories based on the laboratory's hazard assessment:

- Eye and face protection includes:
  - Safety glasses with side shields that perform per the ANSI standards (Z.87), chemical splash goggles, and face shield. Prescription safety glasses can be obtained by contacting the EH&S 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 EH&S.
  - Respirators shall be selected and used in accordance with 8 CCR 5144.
  - Respiratory fit testing is arranged by contacting EH&S at x6727.

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, lab coats)	Visual inspection at each use	Laboratory	8 CCR 3380-3385
Respirators	Visual inspection at each use	Laboratory	8 CCR 5144

ADDITIONAL PROVISIONS FOR WORKING WITH PARTICULARLY HAZARDOUS SUBSTANCES

Specific consideration shall be given to the following provisions when working with acute toxicants, carcinogens, and reproductive toxicants for which general guidance is provided in the General Health and Safety Practices (SP) as indicated:

1) Establishment of designated areas (see SP2).
2) Use of containment devices, such as a fume hood (see SP7) or gloveboxes.
3) Safe handling and removal of waste (see SP11).
4) Decontamination procedures (see SP2).

STANDARD OPERATING PROCEDURES

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 that are applicable to non-chemical activities in laboratories.

LABORATORY-SPECIFIC SOP'S

The Faculty/Lab Supervisor is responsible for providing written Standard Operating Procedures (SOPs) relevant to the health and safety of employees working with hazardous chemicals in their laboratory. As needed, the EH&S Office can review these SOPs. The Faculty/Lab Supervisor must ensure that employees are trained on the use of SOPs applicable to their activities. Laboratory-specific training must be documented.

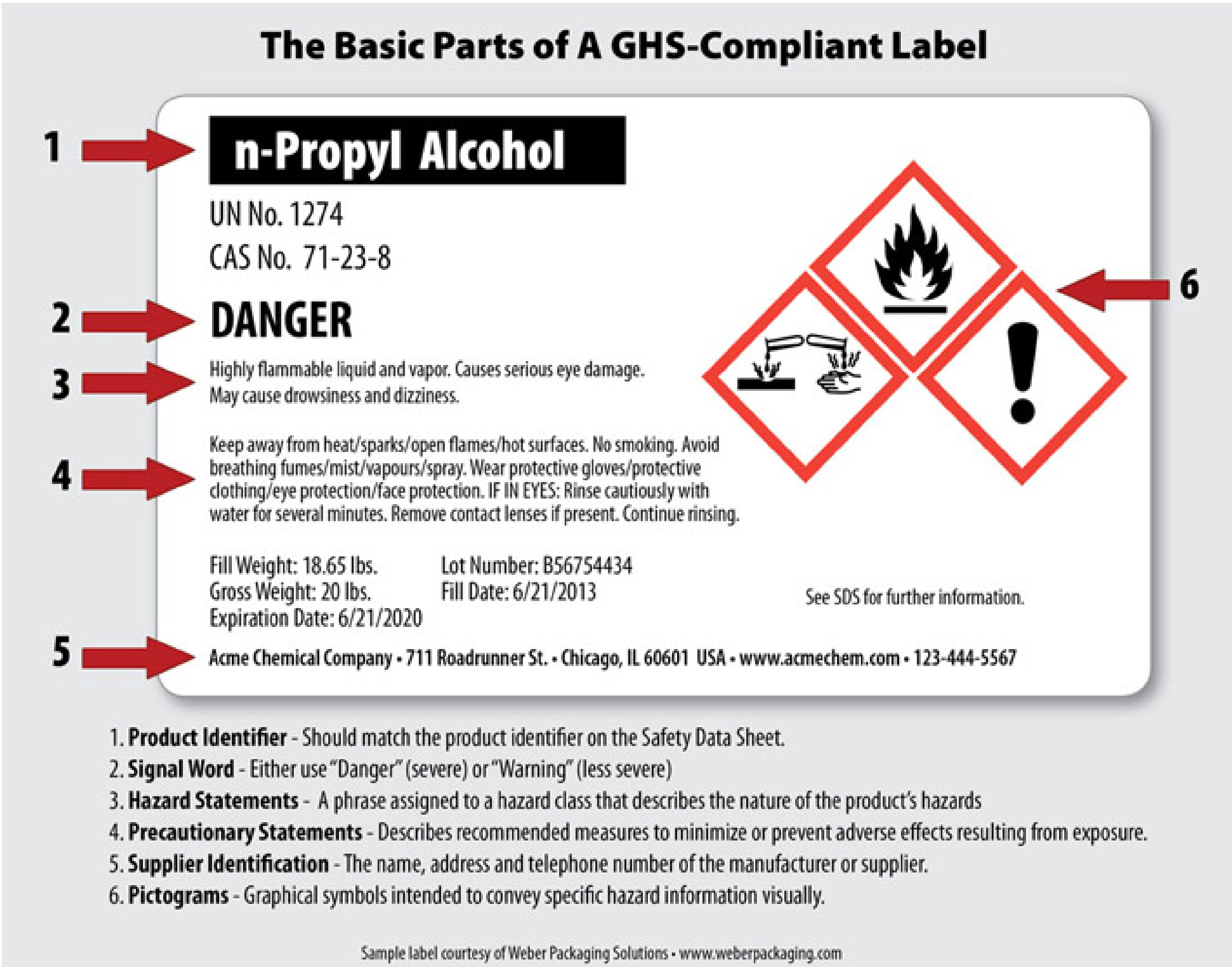
Faculty/Lab Supervisors may also use the Laboratory Risk Assessment Tool to plan a procedure for an experiment. This Tool will help develop an SOP for the health and safety considerations of laboratory work with chemicals.

CHEMICAL LABELING AND STORAGE

LABELING OF CHEMICALS

All containers of materials in the laboratories at Caltech must be properly labeled. Any unlabeled containers with material present is considered a safety risk, and the lab will be responsible for determining the contents or funding of its disposal as an unknown chemical through the Caltech Hazardous Waste Program.

All hazardous chemical manufacturers are required to label chemical containers with Global Harmonized System-compliant labels. Labels from a commercial vendor must not be removed or defaced until the container is completely empty and sufficiently rinsed. The figure that follows shows an example of a GHS compliant label and the required components of a chemical label.



GHS utilizes pictograms (element #6 in the example label above) to communicate different hazards associated with a chemical and the figure below explains each GHS approved pictogram.

Pictograms are used on SDSs, chemical labels, and other places where hazards are communicated.

The table below summarizes the hazards communicated by the pictograms:

Health Hazard	**Flame**	**Exclamation Mark**
		
▪ Carcinogen ▪ Mutagenicity ▪ Reproductive Toxicity ▪ Respiratory Sensitizer ▪ Target Organ Toxicity ▪ Aspiration Toxicity	▪ Flammables ▪ Pyrophorics ▪ Self-Heating ▪ Emits Flammable Gas ▪ Self-Reactives ▪ Organic Peroxides	▪ Irritant (skin and eye) ▪ Skin Sensitizer ▪ Acute Toxicity (harmful) ▪ Narcotic Effects ▪ Respiratory Tract Irritant ▪ Hazardous to Ozone Layer (Non-Mandatory)

Gas Cylinder  ▪ Gases Under Pressure	**Corrosion**  ▪ Skin Corrosion/Burn ▪ Eye Damage ▪ Corrosive to Metals	**Exploding Bomb**  ▪ Explosives ▪ Self-Reactives ▪ Organic Peroxides
Flame Over Circle  ▪ Oxidizers	**Environment (Non-Mandatory)**  ▪ Aquatic Toxicity	**Skull and Crossbones**  ▪ Acute Toxicity (fatal or severe)

Chemical users:

- Must ensure manufacturers' labels on new containers are not removed or defaced.
- Date all Peroxide Forming Chemical containers upon receipt and opening per the directions below.
- Label lab generated containers with the chemical name.
- Label waste containers with a hazardous waste identification tag.

LABELING PEROXIDE FORMING CHEMICALS

Peroxide forming chemicals must be labeled with the **date the container was received** by the laboratory **and the date the container was opened**. These chemicals can degrade into shock sensitive materials over time and therefore must be used or disposed of within certain timeframes, typically 12 months from opening.

To determine if a material is a peroxide forming chemical, refer to the Safety Data Sheet. A list of common examples of peroxide forming chemicals and their storage timeframes can be found here: https://www.sigmaaldrich.com/chemistry/solvents/learning-center/peroxide-formation.html

If a lab can demonstrate that the peroxide former has not developed peroxides, the lab may store the chemical beyond the storage timeframe. If a peroxide forming material of unknown age is found in the lab and/or has signs of crystallization **DO NOT** handle the bottle and contact EH&S at x6727.

CHEMICAL STORAGE

Chemicals must be stored properly to prevent spills, accidental mixing of incompatible chemicals, and the spread of fire. One of the primary considerations when storing chemicals is to segregate incompatible materials. A common control utilized in safe chemical storage and segregation is using secondary containers. A material's SDS should be consulted to determine specific incompatibilities and storage requirements. Tables 2A and 2B give general and specific examples of chemical incompatibilities, respectively.

- Store chemicals in containers that are chemically inert to the substance.
- Store stock quantities of hazardous chemicals in a secure area and in a manner that will not damage the container.

- Segregate incompatible chemicals (See 2A and 2B: Segregation of Incompatible Substances) by utilizing separate storage areas (cabinets) or secondary containment.
- Store corrosive liquid and toxic liquid chemicals in secondary containment.
- Affix appropriate hazard labels to chemical storage cabinets.
- Store flammable liquids in excess of 10 gallons in approved flammable liquid storage cabinets, flammable approved refrigerators, or safety cans.
- Storage of flammables in domestic or normal laboratory type refrigerators/freezers in prohibited. Flammables can only be stored in refrigerators/freezers rated for flammable storage (Flammables approved or explosion proof).
- Minimize flammable amounts in work areas.

Please see General Health and Safety Practices SP6: Chemical Storage for additional guidance and specific storage practices for certain hazard classes of chemicals.

CHEMICAL HAZARD INFORMATION AND TRAINING

HAZARD INFORMATION

To inform employees of the chemical hazards present in their work area, the information below is provided:

- "Occupational Exposure to Hazardous Chemicals in Laboratories", California Code of Regulations Title 8, Section 5191. Cal/OSHA is a governmental agency that protects worker health and safety in the State of California. This regulation specifically addresses the health and safety considerations for employees engaged in use of hazardous chemicals.

- Caltech's Chemical Hygiene Plan. The above mentioned Cal/OSHA regulation requires employers to have a written Chemical Hygiene Plan. The Caltech CHP fulfills this requirement and is a resource for employees to utilize in planning experiments.

- "Permissible Exposure Limits for Chemical Contaminants", California Code of Regulations Title 8, Section 5155. Cal/OSHA establishes permissible exposure limits (PEL) for many chemicals; see Table AC-1 in the link. If a PEL has not been established for a specific chemical, contact EH&S for guidance.

- Reference materials on the hazards, signs and symptoms of exposure, safe handling, storage, and disposal:
  Safety Data Sheets: The Faculty/Lab Supervisor is responsible for ensuring that SDSs are readily available. SDSs are available for most laboratory chemicals used at Caltech at the EH&S website http://www.safety.caltech.edu/sds. Those chemicals for which SDSs are not available on this website must be obtained and maintained at the laboratory where the chemicals are used.
  PubChem: A chemistry database from the National Institute of Health. This searchable database provides information on the health, safety, and toxicity data for chemicals as well as other useful information.

EMPLOYEE TRAINING

Laboratory-specific training is the responsibility of the Faculty. Employees must be trained to understand the hazards of the chemicals with which they work. General chemical hygiene training is available through the EH&S Office and is conveyed in Laboratory Safety Orientation. Please see the Caltech Training Matrix to determine training requirements.

TRAINING RECORDKEEPING

Safety training must be documented. Faculty are responsible for maintaining lab-specific training records. Lab-specific training can be documented using the Workplace Specific Safety Training form.

The EH&S Office maintains records of all EH&S administered trainings.

HAZARDOUS CHEMICAL WASTE MANAGEMENT

Management of hazardous chemical waste is a critical health, 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 the Hazardous Waste Management Guide for the requirements of disposing of hazardous chemicals at Caltech:
https://www.safety.caltech.edu/documents/16478/Hazardous_Waste_Management_Guide.pdf

In addition, the General Health and Safety Practices SP11: Hazardous Waste Guidelines provides general guidance on managing chemical waste in the laboratory.

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 Security and Parking Services website at: https://emergencypreparedness.caltech.edu/Procedures.

CHEMICAL EXPOSURES

It is important to act on chemical exposures immediately following the exposure to minimize any health and safety effects. The initial first aid treatment is dependent on the route of the exposure.

Minor Skin Contact:

- Alert others around you
- Rinse affected area with water for at least 15 minutes
- Notify Supervisor and EH&S Office
- Consult the SDS
- Seek medical attention if necessary

Exposure to Body/Eyes/Clothing:

- Alert others around you
- Remove contaminated clothing
- Rinse affected area with water for at least 15 minutes, using the safety shower or eye wash if necessary

- Call x5000 and notify Supervisor
- Consult the SDS
- Seek medical attention

Exposure by Inhalation or Ingestion:

- Alert others around you
- Evacuate to fresh air
- Call x5000 and notify Supervisor
- Consult the SDS
- Seek medical attention

Exposure by Injection (needles or broken glass):

- Alert others around you
- Wash the affected area immediately with water and soap for 15 minutes
- Call x5000 and notify Supervisor
- Consult the SDS
- Seek medical attention

CHEMICAL SPILLS

In the event of a chemical spill, the first step is to assess the nature of the spill to determine if it constitutes an emergency or if it is safe to clean up. Some chemical spills can be contained and cleaned up by the employee if they have the proper equipment available and are trained to do so. *When in doubt, treat the spill as an emergency.*

Chemical spills **SHOULD NOT** be cleaned by the laboratory and are **considered an emergency** when:

- The substance or hazards are unknown
- The chemical is strongly reactive or explosive
- The spill poses an inhalation hazard and is outside of a fume hood or glovebox (i.e. respiratory protection is needed)
- The spill results in an environmental release, such as entering a drain
- The spill occurs in a public area, such as a hallway

For chemical spills **considered an emergency**:

- Alert others in the area
- Call x5000 from a Caltech phone or 626-395-5000 from an off-campus or cell phone
- Notify Supervisor
- Confine the spill area if possible and safe to do so
- If life safety is threatened, follow evacuation procedures
- Provide pertinent information to emergency responders

For chemical spills **not considered an emergency:**

- Alert others in the area
- Limit access to the affected area
- Consult the Safety Data Sheet

- Wear appropriate personal protective equipment during clean-up
- If necessary, neutralize the spill using applicable neutralizer
- Absorb the spill with appropriate material
- Dispose of all contaminated material as hazardous waste
- Call the EH&S Office at x6727 if assistance is needed

CHEMICAL EXPOSURE ASSESSMENT

Consistent adherence to general safe laboratory practices in conjunction with appropriate use of exposure controls are expected to keep chemical exposures to a safe level. Exposure risk is more likely to increase when handling hazardous chemicals without proper controls in place, such as handling a volatile chemical with an inhalation hazard outside of a fume hood.

For concerns involving hazardous chemical exposure, EH&S can provide a chemical hazard exposure assessment to help verify adequate controls. For more information, please contact EH&S.

PERSONAL MONITORING

A) **When:** Personal monitoring is conducted if there is reason to believe that exposure levels for a substance exceeds the action level (or in the absence of an action level, the permissible exposure limit). For example, personnel developing signs or symptoms associated with hazardous chemical exposure is a reason to conduct monitoring.

B) **Frequency:** The initiation, frequency, and termination of personal monitoring are done in accordance with the relevant regulation.

C) Communication of Results and Recordkeeping: Monitoring results are provided to the employee per the time limits of the relevant regulation or within fifteen (15) days of EH&S's receipt of monitoring results.

EH&S maintains copies of exposure monitoring per regulatory requirements.

MEDICAL CONSULTATION, EXAMINATION, AND SURVEILLANCE

Employees who work with hazardous chemicals will be provided the opportunity to receive medical attention/consultation when:

- Symptoms or signs of exposure associated with a hazardous chemical that the employee may have been exposed to in the lab.
- Exposure monitoring reveals an overexposure.
- A spill, leak, explosion, or other occurrence results in a hazardous exposure (potential overexposure).

SP10: Medical Surveillance provides guidance on the medical surveillance process.

PROVIDERS OF MEDICAL EXAMINATIONS

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.

Licensed Physicians who provide medical consultations and examinations for Caltech employees include:

- Concentra Urgent Care
- Saint George's Medical Clinic

EH&S will obtain a written report from the physician that includes:

- Any recommendation for further medical follow-up.
- Examination and test results.
- Any medical condition that may place the employee at increased risk as a result of exposure to a hazardous chemical in the workplace.
- Statement that the employee has been informed of the results.
- The written report **shall not** reveal specific findings of diagnoses unrelated to occupational exposure.

Caltch's Human Resources are responsible for informing the Faculty/Laboratory Supervisor of any work modifications ordered by the physician as a result of exposure.

INFORMATION PROVIDED TO PHYSICIAN

The Laboratory Group will provide the following information to the physician:

- Identity of hazardous chemicals.
- Safety Data Sheet of the hazardous chemical (if available).
- Conditions of exposure, including exposure data, if available.
- Signs and symptoms of exposure.

RECORDKEEPING OF MEDICAL RECORDS / ACCESS TO MEDICAL RECORDS

- Medical records will be maintained by the Institute Workers Compensation Department in accordance with Caltech's Records Retention Schedule.
- 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 5154.1 – 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 5200-5220. Cal/OSHA Carcinogen List: https://www.dir.ca.gov/title8/sb7g16a110.html.

Carcinogen – chemicals that may cause cancer, typically after repeated or chronic exposure. Their effects may only become evident after a long latency period and may cause no immediate harmful effects. The following references are used to determine chemicals that Cal/OSHA considers a select carcinogen:

- Cal/OSHA Carcinogen List: https://www.dir.ca.gov/title8/sb7g16a110.html.
- Annual Report on Carcinogens by the National Toxicological Program, including all of the substances listed as "known to be carcinogens" and substances listed as "reasonably anticipated to be carcinogens":
https://ntp.niEH&S.nih.gov/ntp/roc/content/listed_substances_508.pdf.
- The International Agency for Research on Cancer, including all of the Group 1, 2A, and 2B chemicals: http://monographs.iarc.fr/ENG/Classification/latest_classif.php.

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

Chemical Waste Program – Caltech EH&S program 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.

CHP – Chemical Hygiene Plan.

CGA – Compressed Gas Association.

CFR – Code of Federal Regulations.

CPC – Chemical Protection Clothing.

DOSH – Division of Occupational Safety and Health.

EH&S – Environmental Health and Safety Office 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, physical, and chemical 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.

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 – Device 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 Coordinator – Lab member appointed by and representing the Facultyfor 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 Faculty/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 Chemical Hygiene Plan (CHP).

SP2: CHEMICAL HANDLING

GENERAL:

- Before handling chemicals, become familiar with hazards, signs and symptoms of exposure, and precautions for preventing exposure. Refer to the materials' SDS for this information, especially section 2 (Hazard Identification), section 4 (First-Aid Measures), and section 8 (Exposure Controls/Personal Protection).
- Do not underestimate hazard risks associated with chemicals or mixtures.
- Avoid contact with all chemicals in the lab.
- Do not taste or smell chemicals.
- Confirm chemicals are labeled.
- 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.
- Inspect glassware prior to use for damage. Do not use broken or damaged glassware.
- Shield or wrap evacuated glass apparatus to contain chemicals and fragments should implosion occur.

CHEMICAL 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.
- Transport incompatible materials in separate outer containers.
- Place contaminated materials in an impermeable, sealed primary container (plastic bag).
- Label outer containers appropriately.

HOUSEKEEPING:

- See General Health and Safety Practices SP14 : Housekeeping Standards.

DESIGNATED AREAS:

A designated area is for work with select carcinogens, reproductive toxins, and other materials with a high degree of acute toxicity (See a limitied list of examples in Table 1: Select Carcinogens, Reproductive Toxins, and Compounds with a High Degree of Acute Toxicity). A designated area may be a fume 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 (see below).
- Store all hazardous chemicals in a secured area.

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. Note that the flushing liquid will be considered hazardous

   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.
   - 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. Still considered hazardous waste

   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. The resulting product is still considered hazardous waste.

   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

If a lab plans on cleaning chemical spills, an effective chemical spill plan should be developed by the lab. 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 Chemical Spill Plan should include:

- Names and telephone numbers of individuals to be contacted in the event of a spill.
- Conditions of a spill that are considered an emergency and therefore should not be cleaned by the lab personnel. See Emergency Response-Spills and Exposures for guidance.

- 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.
- Typical spill control materials include:
  - absorbent materials such as pads, socks, or vermiculite
  - acid and base neutralizers (sodium bicarbonate and citric acid are recommended)
  - dust pan and hand brush or scoop
  - plastic bags to collect contaminated spill materials
  - any additional PPE such as googles, heavy duty gloves, aprons
- 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 appropriate safety glasses or goggles, a lab coat, and gloves 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 a face shield in addition to safety glasses or googles when working with large volumes of hazardous materials or if the material is extremely hazardous.
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 pose a hazard in the laboratory.
7. Wear gloves when working with corrosive, allergenic, sensitizing, or toxic chemicals that are made of materials known to be resistant to permeation by the chemical.
8. Do not wear sandals, open-toed shoes, or perforated shoes in the laboratory.
9. Consult with your Supervisor when there are any changes or new procedures.
10. Inspect all protective equipment before and after use. Do not use defective personal protective equipment. Don’t use contaminated PPE.
11. Laundering of Lab Coats: do not take home, use laundering service available in Alles.

SP4: HYGIENE PRACTICES

PERSONAL HYGIENE

Proper personal hygiene is very important in laboratory work as it helps prevent inadvertent chemical exposures to lab personnel and the public. All chemical users should follow these guidelines:

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

- Confine long hair and loose clothing.
- Wear only non-absorbent, closed-toe shoes.
- Do not eat, drink, smoke, chew gum or tobacco, or apply cosmetics in the lab.
- Do not smell or taste chemicals.

DECONTAMINTION

- 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 a safety shower equipment 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 "Controls to Reduce Exposures to Hazardous Chemicals."
- Flush affected body area(s) for 15 minutes with water.
- Remove contaminated clothing.
- Report usage or activation of the safety showers and eyewashes to EH&S.

SP6: CHEMICAL STORAGE

In addition to the chemical storage requirements outlined in the main body of this CHP, the practices below should also be considered by the laboratory:

- It is recommended to store all hazardous liquid chemicals in secondary containment. **Toxic and corrosive liquids are required to have secondary containment.**
- Keep working quantities of chemicals to a minimum.
- Maintain quantities of chemicals stored to a minimum.
- Do not stack chemicals.
- Do not store corrosives and toxic materials in hard to reach spaces or on upper shelves. Generally, store on shelves that are below eye-level.

Special Storage Considerations are discussed below for compressed gases and highly reactive materials to highlight the unique considerations a lab must take when storing these types of materials.

COMPRESSED GAS CYLINDERS

- See General Health and Safety Practices SP8 : Compressed Gas Cylinders

PYROPHORICS AND HIGHLY REACTIVE MATERIALS

- Suitable storage locations of pyrophoric/highly reactive materials may include inert gas-filled desiccators or gloveboxes; however, some pyrophoric materials must be stored in a flammable substance approved freezer.
- If pyrophoric/highly reactive material is received in specially designed packaging (such as Sigma-Aldrich Sure/Seal™ packaging), ensure that the integrity of that container is maintained.

- Never store pyrophoric/highly reactive materials in a flammable liquids storage cabinet.

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 remain unobstructed.
- The hood is not a substitute for personal protective equipment.
- 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 tag. Only use the hood if it is current, (i.e., flow rate verified within the last year). Only use the hood when the fume hood gauge indicates the hood is fully operational.
- 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 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.
- 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 baffles, which is at the rear of the hood. Blocking the baffles 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 work 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. 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 must 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.

Note for use of local ventilation systems (such as a 'snorkel'): These types of local ventilation systems are not to be used in place of a fume hood. These devices are typically used for odor control or to dissipate heat.

SP8: COMPRESSED GAS CYLINDERS

All compressed gases present a physical hazard due to their high pressure. Many gases, including inert gases, can displace air potentially depleting workplace oxygen content to hazards levels. Certain gases have additional hazards such as flammable, toxic, or reactivity and may have additional safety considerations.

RECEIVING CYLINDERS

- Inspect all incoming cylinders for damage and proper labeling. Do not rely on the color of the cylinder to identify the gas as a vendor may use different colors for cylinders of the same gas.
- Be sure cylinders are not hissing, giving off odors or fumes.
- Do not accept any cylinder that has cracks, bulging, or if the valve fixture shows signs of damage.

SAFE STORAGE PRACTICES

- Store compressed gas cylinders in dry, uncluttered, and well-ventilated areas.
- Store cylinders away from sparks, flames, direct sunlight, and hot surfaces.
- Segregate incompatible gases by storing them at least 20 feet apart or by constructing a non-combustible partition of not less than 18" beyond the sides of the cylinder. A common example of incompatibles are flammable gases and oxidizing gases.
- Cylinders, including lecture bottles, must be stored securely and upright with the valve end up.
- Seismically restrain and secure gas cylinders to prevent them from falling by using two non-combustible restraints (1/3 from the top and bottom) such as chains. Attach them securely and tightly to a wall, rack, or other solid structure.
- When not in use, cylinders must be stored with the valve closed and the protection cap in place.
- Empty cylinders should be clearly marked "Empty" or "MT" and stored separately from charged cylinders.

MOVING AND TRANSPORTING CYLINDERS

- Only trained hazardous materials employees are allowed to transport gas cylinders on public roads. If you need to move a cylinder off campus, please contact EH&S.
- To move a cylinder on Caltech's campus and between labs, a hand truck designed to securely transport cylinders must be used. Do not roll or drag gas cylinders.
- The valve protection cap must be securely in place prior to loading the cylinder onto the hand truck.

GENERAL SAFE USE GUIDELINES

- Always wear approved eye protection when using compressed gases. Refer to the gas SDS for other required personal protective equipment.

- Never attempt to attach a regulator to a gas cylinder without first receiving hands-on training from a knowledgeable user.
- Never use a hammer or wrench to open cylinder or regulator valves. If a valve is difficult to open, it may indicate the valve is damaged or corroded. Return all cylinders to the manufacturer where damage is suspected.
- Make sure that the correct regulator and CGA fitting is being used. See Table 4: CGA Connection Chart. Never try to use adapters to make a regulator with a different CGA number than the cylinder work.
- Do not use plumbers tape on the CGA fitting, which is the connection to the cylinder.
- Stand to the side of the valve outlet when opening the cylinder valve.
- Never refill cylinders or change their contents.
- Do not tamper with or attempt to repair cylinders or regulators.
- Most cylinders have one or more pressure relief devices to prevent rupture of the cylinder if the internal pressure builds to levels beyond the cylinder design limits. Never tamper with the safety relief devices.
- Use an approved leak detection liquid to ensure there are no leaks on gas connections.
- Only use cylinders that are properly labeled with their contents.
- Before removing the regulator from a cylinder, the pressure must be relieved to safely loosen the CGA fitting. DO NOT attempt to loosen a regulator from a cylinder that is still under pressure.
- For an additional resource, see the Compressed Gas Safety Guide and Checklist.

ADDITIONAL PRECAUTIONS FOR CERTAIN GASSES

The information provided below is to be used in addition to the guidelines outlined in SP8. Please refer to the SDS for the gas being used, as gases may have several of the hazards below or other special considerations not covered here.

FLAMMABLE GASSES

- Prior to using flammable gases, inspect the cylinder location and gas use area for ignition or heat sources such as open flames, electricity, sparks, or heat generating equipment.
- Ensure that the flammable cylinder is stored away from incompatible gases and materials such as oxidizers (see SP8: Safe Storage Practices).
- CGA fitting attachments are typically reverse threaded for flammable gases, which are marked with a notch on the center of the regulator CGA fitting.
- Use tubing that are approved for the gas being used. Gas flow through Tygon tubing can generate static electricity, and therefore should not be used with flammable gases.
- Equipment not designed for use with flammables can act as a spark source, so ensure all equipment that comes in contact with the gas is designed for use with flammable gases.
- If possible, consider using a flashback arrestor on the flammable gas system.
- Depending on the experiment specifics, electrical grounding of equipment may be needed to prevent static discharge. Please refer to equipment manuals, SDS's, and EH&S for assistance.

HIGHLY TOXIC AND TOXIC GASSES: The California Fire Code defines highly toxic and toxic gases based on the LC_{50} values of 0-200 ppm and 200-2000 ppm, respectively.

- Highly toxic and toxic gases must be stored and used within a ventilated cabinet or fume hood.
- It is **highly recommended that the smallest sized cylinders of toxic gases be purchased** for use in fume hoods. Lecture bottles of toxic gases can be used in fume hoods, which avoids the need for additional ventilation equipment.
- Depending on the physiological warning properties of a gas, gas detection monitoring may be required.
- Other requirements may apply and it is highly recommended that EH&S be contacted prior to obtaining a toxic gas.

OXIDIZING GASSES

- Ensure that the materials being used to deliver oxidizing gases are approved for use with the gas.
- Exposure of oils and organic materials to oxidizing gases can cause violent reactions or explosions. Therefore, regulators and tubing used with oxidizing gases must be specially cleaned to remove oil and other organic materials.
- Oxidizing gases must be stored away from incompatible materials, such as flammables.

CORROSIVE GASSES

- Periodically check cylinders to confirm that the valve is not corroded or clogged. If the cylinder valve is noticeably corroded, the tank should not be used and removed from the lab.
- Corrosive gases should be used in a ventilated enclosure, such as a fume hood, so it is highly recommended that the smallest amount of gas be purchased for ease of use.

PYROPHORIC GASSES

- Pyrophoric gases are materials that will spontaneously combust upon exposure to air. These are extremely hazardous and must be handled using equipment specifically designed for pyrophoric gases. Please contact EH&S for any questions pertaining to pyrophoric gas use.

SP9: NEW PROCEDURES AND PLANNING AN EXPERIMENT

IMPORTANT FACTORS IN PLANNING AND EVALUATING AN EXPERIMENT

- Evaluate new hazardous procedures with Faculty/Lab Supervisor and the group Safety Coordinator.
- Evaluate the properties of the chemicals to be used, including:
  - Physical properties
  - Reactivity
  - Flammability
  - Radiation
  - Toxicity
  - Biological and health effects
  - Chemical products and byproducts of the experiment and their physical states

SELECT THE APPROPRIATE ENGINEERING CONTROLS

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

PERFORM ADMINISTRATIVE CONTROLS

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

SELECT THE APPROPRIATE PERSONAL PROTECTIVE EQUIPMENT BASED ON THE CHEMICAL PROPERTIES EVALUATION

- Closed-toe shoes
- Full length pants (or the equivalent)
- Safety glasses
- Lab coats
- Aprons
- Face protection
- Shielding
- Appropriate Gloves

Additionally, the Laboratory Risk Assessment Tool can be used to document the above considerations for a new experiment.

SP10: MEDICAL SURVEILLANCE

PURPOSE OF MEDICAL SURVEILLANCE PROGRAM

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 initiate 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 at Caltech rarely trigger medical surveillance provisions.

PAYMENT FOR MEDICAL SURVEILLANCE

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

PROVIDERS OF MEDICAL SURVEILLANCE

Licensed Physicians at:

- Concentra Urgent Care
- Saint George's Medical Clinic

HOW TO OBTAIN A MEDICAL EXAM

Routine Medical Surveillance

- EH&S Assessment:
  - Contact EH&S at x6727 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 EH&S staff may conduct one or more of the following types of monitoring:
    - personal
    - general area of process
    - surface
- Scheduling the Medical Exam:
  - If EH&S evaluation reveals the need for medical surveillance, the employee must schedule an appointment with one of Caltech's Occupational Health Clinics.

Emergencies

- 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 for 15 minutes, removing contaminated clothing) and call Campus emergency x5000 or (626) 395-5000 from a personal device.

SP11: HAZARDOUS WASTE GUIDELINES

All chemical wastes will be disposed of in accordance with the Caltech Hazardous Waste Management Guide. Below is a summary of the primary requirements of the Hazardous Waste Program to assist researchers with their hazardous waste management in the laboratory.

COLLECTING HAZARDOUS CHEMICAL WASTE

- Do not purchase more of a chemical than you expect to use in the near future. The cost of disposal often exceeds the purchase price of the chemical.
- Do not use chemical evaporation in fume hoods or drains to dispose of hazardous waste.
- Ensure containers are chemically compatible with the waste being collected.
- Waste containers must be kept closed except when adding hazardous waste.
- Hazardous waste containers must be labeled with an Institute Hazardous Waste Identification Tag as soon as the first drop of hazardous waste is added to the container. No other forms of hazardous-waste identification are acceptable.
- Do not fill a waste container completely to the top; 90% of the volume of the container is considered full.
- Do not collect incompatible chemicals in the same waste container. Utilize secondary containment to segregate incompatible hazard classes and to act as spill control.
- Label secondary containers with a Satellite Accumulation Area (SAA) sticker.
- Collect contaminated lab debris in a sealable bag or container that is affixed with an Institute Hazardous Waste Identification Tag.

HAZARDOUS CHEMICAL WASTE DISPOSAL

- EH&S must receive requests for pick-up of 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.
- All waste ready for disposal must be located in a SAA.
- Container must be free of external contamination.
- Hazardous waste tag must be checked 'ready for pick-up'.
- If a special request for an additional pick-up is needed (large number of bottles, lab clean out, experiment ended, etc.) submit a request through the Facilities Service Requests portal.
- Contact EH&S in advance of any lab clean outs to ensure timely removal of hazardous waste.

MANAGING EMPTY CONTAINERS

- Containers need to be triple rinsed before reuse or disposal. The rinsate is to be collected as hazardous waste.
- Container must be compatible with the material being placed in the container.
- Dispose in glass waste container or if container is plastic it can be disposed of as general laboratory trash.
- Original labels need to be defaced prior to empty container reuse or disposal.

WASTES THAT REQUIRE SPECIAL HANDING

- Unknowns: Arrangements for chemical analysis of unknowns can be made through EH&S. Costs associated with identifying waste are charged back to the research group.
- Peroxide forming chemicals that are found without receiving/opening dates need to be assessed prior to removal from the lab to ensure they are safe to move. Any signs of crystallization presents an immediate danger and should **NOT BE HANDLED**. Call EH&S immediately if crystallization is seen or suspected.
- Dry picric acid is explosive. **DO NOT HANDLE** dry picric acid. Call EH&S immediately.
- Sharps contaminated with chemicals need to be collected in a puncture resistant container that has a lid. Sharps containers need to be labeled with a Hazardous Waste Identification Tag at all times.
- Piranha etch and aqua regia: Collecting these materials as waste is discouraged as gaseous by-products form over time and can lead to explosions if not stored correctly. If wastes of these materials needs to be collected, **GLASS** containers must be used with vented caps to allow excess pressure to escape.

SP12: WORKING WITH CRYOGENICS

Cryogenic liquids are characterized by having a boiling point of less than -90 °C (-130 °F). Another physical property of cryogenic fluids is the high-volume-expansion ratio in the liquid-to-gas phase. These properties necessitate that a number of general precautions and safe practices be used, which are outlined below.

There may also be special precautions that need to be considered when a cryogenic liquid has additional hazards to those discussed below. Users of cryogenic liquids must be familiar with the hazards by reviewing a material's SDS and receiving training as needed.

GENERAL HAZARDS:

1) **Extreme cold**: All cryogenic liquids are extremely cold. Contact can cause tissue damage and can cause many common materials, such as rubber and plastic, to become brittle. Safe practices, personal protective equipment, and material compatibility with cryogenic work must be considered to mitigate this hazard.
2) **Large volume expansion when vaporized**: All cryogenic liquids produce large volumes of gas when they vaporize. One volume of liquid nitrogen, for example, expands to 694 volumes of gas when vaporized at 1 atm. If these liquids vaporize in a sealed container or piping, they can produce large pressures that could cause a rupture. For this reason, containers and piping used for handling cryogenic liquids must allow pressure to escape as the liquid vaporizes.
3) **Asphyxiation**: Vaporization of cryogenic liquids, expect oxygen, in enclosed areas without sufficient ventilation can cause asphyxiation by displacing the air. Storage of cryogenic containers and work with cryogens must occur in well-ventilated areas.

SAFE USE: Prior to using any cryogenic liquid, the user must be familiar with the hazards. The information below should be supplemented with any lab-specific usage protocols and training.

- 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, such as a lab coat
    - Coverage of all skin below the waist. Long pants should not have cuffs, which can trap spilled cryogenic liquids
    - Closed-toe shoes
- In general, low pressure cryogenic cylinders should be used for withdrawing liquid cryogenics, such as nitrogen.
- Transfer cryogenic liquids from large liquid cylinders using transfer hoses designed for the particular application.
- Slowly open liquid dispensing valves on liquid cylinders to minimize splashing and boiling.
- Boiling and splashing always occurs when filling warm containers or inserting objects in cryogenic liquids. Stand clear of boiling and splashing.
- Dewar flasks used to collect cryogenics for use in the lab should have a cap that allows built-up pressure to escape and keep air and moisture out.
- Use tongs to immerse or remove items from cryogenic liquids. Never immerse any body part, including hands, even if PPE is being worn.
- Choose materials designed for use with cryogenics that are also chemically compatible.
- 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 cylinders and dewars.

If there is a cryogenic spill, immediately leave the area and report to the Faculty or Safety Coordinator. 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.

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.
- Unplug equipment if emergency occurs without raising fume hood sash-unplug from outlet external to fume hood.

2. UNATTENDED REACTIONS

- Except in rare instances and with appropriate safety measures in place, 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.
- Post signage close to the operation with information on the reaction, hazards, and emergency information. A suggested sign to use for unattended experiments can be found here: https://www.safety.caltech.edu/documents/16488/Reaction_in_Progress_Sign.pdf
- Additional guidance on unattended experiments can be found here: https://www.safety.caltech.edu/documents/16487/Guidance_for_Unattended_Experiments_2qcu3cG.pdf

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 aisles, exits, emergency equipment (eyewash/safety showers, fire extinguishers), electrical panels, and other emergency equipment shall remain unobstructed**
    - In case of an emergency, personnel will need to safely evacuate or have access to the emergency equipment.
    - Do not leave solvent containers on the floor.
    - Remove excess cardboard boxes, Styrofoam, or any other combustibles from the lab.
    - Doors shall never be blocked with any items.
- **Lab benches and fume hoods shall be kept clean and clear of excess clutter**
    - There should be no signs of contamination on work surfaces. Clean work areas to minimize the possibility of contaminating personnel and experiments.
    - Make a clear demarcation between "wet" and "dry" areas where paperwork is done.
    - Excessive clutter can exacerbate or cause an emergency situation (chemical spill, fire). Eliminate clutter from counters and the lab overall.
    - Clutter in fume hoods can impede the airflow, increasing the possibility of chemical exposure.
    - The work area shall be cleaned on a regular basis and as needed.
    - Place all chemicals in a proper storage area by the end of each workday.
- **Chemical containers shall be clean, properly labeled, and returned to an appropriate storage area upon completion of usage**
    - Allows other laboratory workers to easily find chemicals, prevent incompatible storage, and help maintain complaint volumes of chemicals.
    - Use secondary containment (spill trays, plastic tubs) to store corrosives, particularly hazardous substances, and liquid hazardous waste.
    - Use secondary containment to segregate incompatible chemicals.
    - Keep chemicals in properly sealed containers, upright, and avoid stacking.
- **Remove gloves where glove usage is not universal**
    - Glove removal may be needed when working on shared lab computers or other lab equipment.
    - Gloved hands should never contact common/public used items, such as door handles and elevator buttons to avoid cross-contamination.
- **All chemical wastes will be disposed of in accordance with the Caltech Hazardous Waste Management 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.**

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

Alkylating Agents	***N*-Nitroso Compounds**
α-Halo ethers	*N*-Nitrosodimethylamine
Bis(chloromethyl) ether	*N*-Nitroso-*N*-alkyureas
Methyl chloromethyl ether	
Sulfonates	**Aromatic Amines**
1,4-Butanediol dimethylsulfonate (myleran)	Benzidine (4,4'-diaminobiphenyl)
Diethyl sulfate	α-Napthylamine
Dimethyl sulfate	β-Napthylamine
Ethyl methanesulfonate	Aniline
Methyl trifluoromethanesulfonate	
	Aromatic Hydrocarbons
Acylating Agents	Benzene
β-Propiolactone	Benz[*a*]anthracene
β-Butyrolactone	Benzo[*a*]pyrene
Dimethylcarbamyl chloride	
	Natural Products (including antitumor drugs)
Organohalogen Compounds	Adiramycin
1, 2-Dibromo-3-chloropropane	Aflatoxins
Mustard gas (bis (2-chloroethyl) sulfide)	Bleomycin
Vinyl chloride	Cisplatin
Carbon tetrachloride	
Chloroform	**Miscellaneous Organic Compounds**
3-Chloro-2-methylpropene	Formaldehyde
1,2-Dibromoethane	Acetaldehyde
1,4-Dichlorobenzene	1,4-Dioxane
Trichloroethylene	Urethane (ethyl carbamate)
2,4,6-Trichlorophenol	

Methyl iodide	**Miscellaneous Inorganic Compounds**
	Arsenic and certain arsenic compounds
Hydrazines	Chromium and certain chromium compounds
Hydrazine (and hydrazine salts)	Nickel compounds
1,2-Diethyl hydrazine	Beryllium and certain beryllium compounds
1,1-Dimethyl hydrazine	Cadmium and certain cadmium compounds
1,2-Dimethyl hydrazine	Lead and certain lead compounds

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

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 CONPOUNDS WITH A HIGH DEGREE OF ACUTE TOXICITY

Acrylic acid	Chlorine	Ethylene oxide
Acrylonitrile	Cyanide salts	Hydrazine
Allylalcohol	Diazomethane	Hydrogen cyanide
Allylamine	Diborane (gas)	Hydrogen fluoride
Arrolein	1,2-dibromethane	Hydrogen sulfide
Bromine	Dimethyl sulfate	Methyl fluorosulfonate

Methyl iodide	Osmium tetroxide	Sodium azide
Nickel carbonyl	Ozone	
Nitrogen dioxide	Phosgene	

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

TABLES 2A and 2B: 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. Table 2A is a general guide for determining incompatible substances, but Safety Data Sheets should also be utilized for chemicals to determine any specific incompatibilities.

Table 2A: General Hazard Class Incompatibilities. In general, the pair of hazard classes marked with an X are incompatible with one another.

	FLAMMABLE LIQUIDS	OXIDIZERS	ORGANIC ACIDS	INORGANIC ACIDS	BASES	WATER REACTIVES	AQUEOUS SOLUTIONS	CYANIDES
FLAMMABLE LIQUIDS		X		X				
OXIDIZERS	X		X					
ORGANIC ACIDS		X		X	X	X		X
INORGANIC ACIDS	X		X		X	X		X
BASES			X	X				
WATER REACTIVES			X	X			X	
AQUEOUS SOLUTIONS						X		X
CYANIDES			X	X			X	

Table 2B: Specific Examples of Incompatible Chemicals

Chemical	Incompatible with
Acetic Acid	Chromic acid, nitric acid, perchloric acid, peroxides, permanganates

Chemical	Incompatible with
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
Hydrocyanic Acid	Nitric acid, alkali
Hydrofluoric Acid (anhydrous)	Ammonia (aqueous or anhydrous)

Chemical	Incompatible with
Hydrogen Peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases
Hypochlorite’s	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 FOR GLOVES

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 solution for exposure.

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												
22. Acetaldehyde	21	3	NR	5	55	3	13	5	ND	0	NR	5

Chemical by Class	Neoprene		Nitrile		Rubber		PVC		Butyl		Viton	
	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC	BDT	CPC
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

CYLINDER GAS TYPE	CHEMICAL SYMBOL	CGA CONNECTION Standard/Alternate
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
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

CYLINDER GAS TYPE	CHEMICAL SYMBOL	CGA CONNECTION Standard/Alternate
“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
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

CYLINDER GAS TYPE	CHEMICAL SYMBOL	CGA CONNECTION Standard/Alternate
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
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

CYLINDER GAS TYPE	CHEMICAL SYMBOL	CGA CONNECTION Standard/Alternate
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