UNIVERSITY of HOUSTON

Chemical Hygiene Plan

Guidelines for the Safe Handling of Hazardous Chemicals

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Environmental Health and Life Safety (EHLS)
http://www.uh.edu/ehls/

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1.0 Introduction

The purpose of this Chemical Hygiene Plan is to define work practices and procedures in order to protect students, laboratory workers, researchers, and supervisors at the University of Houston from the health and physical hazards associated with the use of hazardous chemicals. The Chemical Hygiene Plan is consistent with the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) standard entitled "Occupational Exposures to Hazardous Chemicals in Laboratories" (Code of Federal Regulations, 29 CFR 1910.1450) and the Texas Hazard Communication Act (Chapter 502 of the Texas Health and Safety Code).

OSHA has defined a hazardous chemical as "a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees." In addition, OSHA defines a laboratory as "a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis." Finally, laboratory workers are defined in the OSHA Lab Standard under the definition of "employee" as "an individual employed in a laboratory workplace that may be exposed to hazardous chemicals in the course of his or her assignments."

UH Environmental Health and Life Safety (EHLS) defines laboratory personnel as Principal Investigators, Laboratory Managers/Supervisors, Research Scientists, Postdoctoral Fellowships, Temporary Visiting Researchers, Graduate Students, Undergraduate Students, High School Students and Volunteers working in the laboratory. If there is any confusion about whether a particular workplace is considered a laboratory that utilizes hazardous chemicals, or whether someone is considered laboratory personnel, EHLS will, upon request, make this determination.

All laboratory personnel must be familiar with this Chemical Hygiene Plan and together share the responsibility for creating a safe and healthy work environment. In addition to the Chemical Hygiene Plan, laboratory personnel shall be cognizant of and adhere to the procedures outlined in the Biological Safety Manual, Radiation Safety Manual and Regulated Waste Manual. These documents are available on the EHLS website at http://www.uh.edu/ehls/about/manuals/. Further information is available by contacting EHLS at 713-743-5858 or ehls@uh.edu.

2.0 Responsibilities

Environmental Health and Life Safety's main purpose is to support the University of Houston in its mission of higher education and research. The Department's efforts are directed at assisting the University in identifying safety hazards and controlling such hazards through protective equipment, hazard mitigation methods, and the development and presentation of safety training programs.

2.1 Chemical Hygiene Responsibilities

2.1.1 Deans, Directors, and Heads of Academic and Administrative Units

Deans, Directors, and Heads of Academic and Administrative Units have the primary responsibility for the health and safety of their staff and students. Specific responsibilities regarding the implementation of the Chemical Hygiene Plan include:

- Ensure compliance with all requirements for chemical safety and hygiene within their departments and colleges;
- collaborate with faculty and staff to adapt this Chemical Hygiene Plan to include lab-specific guidelines and to develop strategies to implement the Plan;
- make budget arrangements for health and safety improvements.

2.1.2 Principal Investigators and Designees in Charge of Supervising Laboratories

Principal Investigators and Designees in charge of supervising laboratories have the following responsibilities for implementing the Chemical Hygiene Plan:

- Perform hazard assessments, develop/approve laboratory-specific standard operating procedures (SOPs) for all hazardous chemicals and procedures;
- inform and train laboratory personnel concerning chemical safety as required by this Plan and retain training records and all documentation;
- implement and enforce rules and standards concerning health and safety for laboratories;
- ensure compliance of laboratory personnel with this Plan;
- ensure the availability and enforce the use of: appropriate personal protective equipment, Safety Data Sheets (SDSs), and relevant reference materials;
- remain cognizant of chemicals stored and used in laboratories and their associated hazards;
- dispose of chemicals no longer needed by submitting an on-line waste pick up request to Environmental Health and Life Safety;
- conduct internal inspections of laboratories for health and safety concerns; and,
- request assistance from Environmental Health and Life Safety as needed.

It is the responsibility of the Principal Investigator or Designee to ensure that Particularly Hazardous Substance (PHS) determination is conducted on all existing chemical inventories and on all future chemical purchases. Furthermore, prior to beginning work with a PHS, or once the PHS determination is made, Principal Investigators or Designees shall complete a lab-specific PHS Standard Operating Procedure (PHS SOP). Principal Investigators must ensure that

laboratory personnel are trained, understand, and implement the procedures as directed in the SOP. For more information please see Chapter 5.

2.1.3 Laboratory Personnel

Laboratory personnel's responsibilities regarding implementation of the Chemical Hygiene Plan are as follows:

- Complete General Laboratory Safety Orientation and other lab-specific trainings provided by EHLS and the Principal Investigator before undertaking any activity in the laboratory;
- plan and conduct laboratory operations in accordance with this Chemical Hygiene Plan and lab-specific documentations;
- report all hazardous conditions to the Principal Investigator or Designee;
- wear or use appropriate Personal Protective Equipment (PPE);
- report any job-related injuries or illnesses to the Principal Investigator or Designee and seek treatment immediately;
- refrain from the operation of any equipment or instrumentation without proper instruction and authorization;
- remain aware of the hazards of the chemicals in the laboratory and how to handle, store and segregate hazardous chemicals safely;
- request information and training if unsure how to handle a hazardous chemical or perform a dangerous procedure.

All laboratory personnel approved to work with a particularly hazardous substance (PHS) shall be trained by the Principal Investigator or Designee and strictly comply with all instructions and procedures. For more information please see Chapter 5.

2.1.4 Environmental Health and Life Safety Department (EHLS)

Specific to this Chemical Hygiene Plan, the responsibilities of the Environmental Health and Life Safety Department include the following:

- Provide technical assistance to laboratory personnel concerning appropriate storage, handling and disposal of hazardous chemicals;
- provide general and specialized laboratory safety training;
- conduct exposure assessments and laboratory surveillance as needed or upon request;
- make routine, as well as special, health and safety audits;
- provide technical assistance concerning personal protective equipment and laboratory safety equipment;
- remain current on industrial best practices, standards, rules and regulations concerning chemicals used at University of Houston.

2.2 General Responsibilities

Preventing workplace injuries, exposures, and illnesses is the responsibility of every member of the campus community. Specific responsibilities are assigned to more senior members of the research and teaching community in order to implement, and ensure compliance with this Plan by their subordinate personnel.

2.2.1 The Chancellor

The Chancellor has overall responsibility for compliance with health and safety requirements at all facilities and programs under campus control.

2.2.2 Vice Chancellor for Research

The Vice Chancellor for Research is responsible for the implementation of this Plan in all applicable research and teaching laboratories within his or her jurisdiction.

2.2.3 Deans, Department Chairpersons

Deans and Department Chairpersons are responsible for communicating, promoting and enforcing this Plan in their respective research and teaching areas.

2.2.4 Principal Investigators and Laboratory Management Staff

Principal Investigators and laboratory management staff are responsible for complying with this Plan and ensuring their laboratory personnel receive appropriate training and comply with this Plan as it relates to their research and teaching activities.

2.2.5 All Laboratory Personnel

All laboratory personnel are responsible for following all safety requirements including how to work safely with substances designated as particularly hazardous substances.

2.2.6 The UH Department of Environmental Health and Life Safety (EHLS)

EHLS is responsible for inspection of laboratories and for monitoring campus compliance with this Plan. In cases where laboratory activities pose an immediate danger to life or health, designated EHLS staff have the responsibility and authority to order the temporary cessation of the activity until the hazardous condition is abated.

2.2.7 The UH Chemical Hygiene Officer

The Chemical Hygiene Officer, also referred to as the Chemical Safety Officer, is responsible for facilitating necessary reviews of procedures that involve the use of hazardous materials. The reviews of procedures shall accommodate the requirements of this plan as well as other current and applicable guidelines and regulations.

3.0 Control Measures

3.1 Engineering Controls

The primary objective in controlling occupational exposures is to prevent contamination of the work atmosphere. This shall be achieved first by use of a chemical fume hood, or other enclosure. The second way in which this is achieved is by making sure the ventilation is such that the air pressure in the laboratory is negative with respect to the hallway, thus assuring airflow into the laboratory.

3.1.1 Fume hood

The best way to prevent exposure to airborne hazards is to prevent their escape into the working atmosphere by use of hoods and other ventilation devices. Operations such as running reactions, heating or evaporating solvents, and transfer of chemicals from one container to another must be performed in a hood when there is reasonable potential for hazardous material exposure.

Fume hoods will conform to the following specifications.

- Where applicable, the hood shall have a working sash.
- When the hood sash is open approximately eighteen (18) inches, an average face velocity of 80-120 feet per minute (FPM) at the hood face shall be provided.
- The hood enclosure must be fire- and chemical-resistant.
- In new construction, consideration shall be given to locating the hood such that ambient air currents do not unacceptably reduce the containment efficiency of the hood.
- In new construction the hood shall be designed to produce laminar airflow.
- The hood shall have only modifications approved by EHLS. Any modification must not detract from the hood performance.
- In new construction, the room in which the hood is located shall have a source of sufficient make-up air to replace the air that is exhausted out.
- The fume hood must be appropriate for the material used within (e.g., perchloric acid usage).
- Airflow shall be such that contaminants within do not escape the fume hood, such as shown by a smoke test.

Face velocity and airflow monitors will be evaluated by EHLS upon installation of chemical fume hoods. Each chemical fume hood at University of Houston is recertified annually for usage and performance. Where performance parameters fall outside specifications, work orders are initiated by labs to repair the hoods. When appropriate, a notice is placed on the fume hood indicating that it is not to be used until its performance is within the specified performance parameters.

Non-venting hoods (e.g., laminar flow hoods with in-room venting) shall be clearly labeled as such. No work with volatile hazardous chemicals shall be performed in hoods that do not vent outdoors.

Laboratory personnel must confirm adequate hood performance before use and utilize the chemical fume hoods properly.

- Check if the hood has a yellow sticker on it and that the date on the sticker is not past the due date. If it is due, contact EHLS immediately for recertification.
- New fume hoods must be equipped with air flow monitoring devices which will alert the user if there is a problem with air flow. For older hoods without air flow monitoring devices, a simple visible test to ensure flow into hoods and other ventilating devices is to tape a Kimwipe to the hood below the sash and note its movement when the exhaust fan is on.
- Typically it is best to maintain the hood sash at a working height of 18 inches.
- Work at least 6 inches inside hood.
- Always close the fume hood sash when finished with the hood or when leaving experiments unattended.
- Laboratory personnel must be vigilant that their fellow lab personnel maintain closed sashes when they are not working at their hoods.
- Only ongoing experiments may be in the chemical fume hood and must not block air flow. Chemical fume hoods must never be used as chemical storage locations.
- Proper use of combination sash fume hood.
  - Combination sash hoods increase the flexibility of the fume hood, and reduce time and money spent on reconfiguring laboratory set-ups in order to move to the next task. When opening one vertical side of the sash to set up, laboratory personnel should shield themselves by standing behind the other closed vertical sash.
  - Combination sash hoods rely on completely closing the vertical sash while working through the horizontal sliders. Regular use of the horizontal sliding panels with the vertical sliding sash closed reduces chemical exposure and reduces energy expense.
  - The vertical sliding sash must only be open during set up, not while manipulating objects in the hood with reactions present. Always close the sash when finished with the hood or when leaving experiments unattended.

Protective equipment other than chemical fume hoods must be checked periodically by the Principal Investigator or Designee to ensure that the equipment is functioning properly. Any questions or requests for assistance in evaluation of hoods and other protective equipment shall be directed to Environmental Health and Life Safety (EHLS) at 713-743-5858.

Malfunctioning fume hoods must have the sash closed down completely and be marked “Do Not Use” if they are to be repaired. For more information please see 3.4.2 Housekeeping, Maintenance, and Inspections section. To re-start an “Out of Service” fume hood, contact EHLS. Malfunctioning eyewashes and safety showers must also be marked “Do Not Use".

3.1.2 Other Local Ventilation Devices

Exhaust air from glove boxes and isolation rooms must release into the hood exhaust system or its own ducted system. For more information please refer to General Laboratory Safety Manual.

3.1.3 Special Ventilation Areas

Procedures involving radioactive aerosols, powders or gaseous products, or procedures that could produce volatile radioactive effluents shall be conducted in an approved hood, glove box or other suitable closed system. Such fume hoods shall be designed with smooth, non-porous materials and possess adequate lighting to facilitate work within. The hoods shall have a minimum face velocity of 100 FPM. Contact the Radiation Safety Office for further information on hoods for radioactive materials.

3.2 Personal Protection Equipment/Hygiene

Each laboratory must have accesss to protective apparel and equipment appropriate for the hazards present. Appropriate protective apparel and equipment shall be determined by the Principal Investigators or Designee in consultation with EHLS. The Principal Investigators or Designees must assure that all laboratory personnel, including visitors, wear appropriate PPE where chemicals or hazardous materials are stored or used. Personal hygiene is another very basic aspect of laboratory safety. Wearing appropriate personal protection and practicing good personal hygiene, as described below, will greatly minimize exposures to hazardous chemicals during routine use and in the event of an accident.

- **Attire.** Legs and feet must be covered by closed-toe shoes, long pants or skirts which fully cover the legs (no sandals, open-toed shoes, or shorts), long hair must be confined and loose clothing and jewelry must be secured before beginning work. Wear a properly fastened lab coat specific for the hazards of the procedures performed in the laboratory. This includes, but is not limited to, using flame resistant clothing for use with pyrophorics, acid resistant protection when working with acids (especially HF or other strong acids), and protective items when working with hot or cold materials. The Principal Investigator or Designee is responsible for enforcing the protective clothing policy. More information will be available in "Appendix 1. UH Laboratory Dress Code Policy".

  Any laboratory personnel who is not wearing proper attire or PPE will be asked to leave the laboratory immediately by EHLS until the situation is corrected.

- **Gloves.** Gloves are essential when working with hazardous substances. The proper gloves will prevent skin absorption, infection or burns. All glove materials are not equally effective in protection from chemical hazards. In many cases, latex examination gloves do not provide adequate protection from hazardous chemicals. Consult the Safety Data Sheet (SDS) of the chemical or the glove manufacturer, Chemical Resistance Selection Chart for Protective Gloves or contact EHLS for assistance in appropriate selection.

- **Eye protection.** Safety glasses or chemical goggles must be donned before entering any wet bench laboratory and any laboratory where soldering or machining/grinding occur. This applies to all laboratory personnel, visitors, and facility maintenance staff and contractors. Goggles are recommended when chemical splashes are possible. Safety glasses or goggles must be worn over prescription glasses and must be of a type intended to be worn over prescription glasses. The wearing of contact lenses in laboratories is an unsettled issue. If contact lenses are to be worn, the eyes must be protected by goggles when in the laboratory. The Principal Investigator or Designee will determine the level of eye protection required. All eye protection used must meet ANSI Z87.1 requirements.

Safety glasses shall be chosen to conform to the wearers face and minimize gaps around the glasses. Prescription safety glasses are acceptable as long as they have side shields for splash protection and conform to the wearer's face. EHLS shall be consulted to assist in selecting proper eye protection.

- **Face shields.** Face shields worn over safety glasses may be required for certain processes as determined by the Principal Investigator (PI). Full-face shields must be worn when conducting a procedure that may result in a violent reaction. Full-face shields with bottom caps to protect under the chin are preferred due to the tendency to raise the chin when a splash occurs.

- **Hearing Protection.** Hearing protection will be provided for anyone working in an area where the sound levels exceed 85 dBa. Contact EHLS to measure noise levels, to recommend proper hearing protection, and to evaluate the need for noise reduction engineering controls.

- **Personal hygiene.** Hands shall be washed frequently throughout the day, before leaving the laboratory, after contact with any hazardous material, before eating, etc.

3.3 Administrative Controls

3.3.1 General Standard Operating Procedures in a Chemical Lab

This plan provides a minimum set of guidelines for the handling of hazardous chemicals on campus. Individual administrative units, laboratories or research groups are required to develop more detailed procedures as their situations warrant. Laboratory-specific standard operating procedures are required for Particularly Hazardous Substances, or PHSs (more see 5.0 Particularly Hazardous Substances (PHSs). Other chemical classes (such as explosives, peroxide formers, or pyrophoric materials) will also need lab-specific SOPs. In all situations, Principal Investigators or Designees will be responsible for enforcing adequate safety and hygiene measures in laboratories they supervise. If necessary, additional assistance from EHLS is available.

Some rules or standard operating procedures, which apply to all laboratory personnel at UH include the following:

- **Complete trainings**: complete required EHLS trainings and lab-specific chemical trainings by PI or the designee prior to beginning work. Training requirements can vary depending on the type of research being conducted. General Laboratory Safety training and other trainings provided by EHLS will be documented by Environmental Health and Life Safety. Principal Investigator or Designee is to keep documentation of all lab-specific chemical trainings and submit to EHLS upon request. More please see Chapter 2.0 Safety Training in General Laboratory Safety Manual and Chapter 5.3 PHS SOP in this Plan.
- **Be familiar with University Safety Plan/Manuals/Policies**: Familiarize yourself with the University's General Laboratory Safety Manual, Chemical Hygiene Plan, Biological

Safety Manual, Radiation Safety Manual and Regulated Waste Manual. Every laboratory using hazardous chemicals, radioactive, or biological hazards must have a copy of the respective manuals in the lab or otherwise readily available. These manuals are readily available on the EHLS website. Thoroughly review all applicable safety manuals with laboratory personnel.

- **Update Chemical Inventory annually and keep Safety Datasheets on files**. All laboratories are required to keep an updated copy of their chemical inventory on file, which must be made available to EHLS upon request. Lab personnel must know how to get SDSs; either paper copies in the lab, or the internet. Regardless of the system used, SDSs must be available at all times. More please see 3.3.2 Chemical Inventory of this Plan.
- **Complete risk assessment and then SOP**: Incorporate risk assessments when planning out experiments, and write Standard Operating Procedures before beginning new processes/operations. More please see Chapter 5.3 PHS SOP in this Plan.
- **Plan for emergencies** and know the location of emergency eyewashes and showers, spill kits, fire extinguishers, and fire pull stations. In the event of a chemical spill which is beyond the capability of the laboratory personnel, notify EHLS immediately after providing first aid and/or getting help.
    1. During business hours (M-F/8-5) call 713-743-5858.
    2. After hours call 911 on campus phone or 713-743-3333 to be routed to EHLS staff on call.
- **Properly label** all chemical containers, including oil/water baths, squirt bottles, etc..
- **Properly label and disposal of chemicals**. To request a pickup of chemicals, submit online UH Hazardous Waste Pickup Request Form. Disposal of all laboratory waste shall follow the procedures outlined in the “Regulated Waste Manual". A laboratory waste minimization program is also coordinated by EHLS. Please consult the Regulated Waste Manual for detailed information.
- **Follow Other lab rules to ensure chemical safety:**
    1. **No smoking**.
    2. **Never work alone** with any hazardous chemicals/materials or operations.
    3. **Wear PPE and appropriate apparel**, including clothing that covers the legs, closed toe solid top shoes, and safety glasses; wear gloves and a lab coat when working with hazardous materials.
    4. **Follow additional PPE requirements** depending on the type of research being conducted.
    5. **Keep aisle ways clear**. Do not block access to emergency equipment or exits.
    6. **Store chemicals in appropriate storage locations**. Do not store chemicals on floors and keep storage outside chemical cabinets to a minimum.
    7. **No Food or Drink Rule Observed**. Eating, drinking and the application of cosmetics are not permitted in areas where hazardous chemicals are used and shall be done only in well defined designated non chemical areas. Never store food or drink in the same refrigerator with chemicals, biohazards or radioactive materials.
    8. **No horseplay**. Practical jokes or other behavior that might confuse, startle, or distract another worker is not permitted.
    9. **Mercaptans (thiols, sulfhydryl reagents)**. To avoid false reporting of natural gas leaks, EHLS shall be contacted at 713-743-5858 when mercaptans will be used in a laboratory in such a manner that persons outside of the laboratory could smell the

mercaptan and suspect a natural gas leak in the building. All experiments in which mercaptans are used must be performed in a chemical hood.

10. **Use proper equipment that is in good condition.** For example, never use chipped or cracked glassware. Shield pressurized or vacuum apparatus and safeguard against bumping or overheating. When inserting glass tubing into stoppers, lubricate the tubing and protect hands from being cut in the event the tubing slips and breaks.
11. **Mouth pipetting is not permitted.**
12. **Heat Sources Separated from combustibles.** Ignition sources include electrical outlets, lighting fixtures, switches, exposed machinery components, as well as open flames.
13. **Appropriate Clearance to Ceiling.** It is required that there is an 18 inch clearance to the ceiling to comply with NFPA codes for fire sprinkler systems and a 24 inch clearance in rooms which are not equipped with sprinklers.
14. **Electrical Circuit Loading and Cords**. Insufficient or overloading of electrical outlets must be avoided.
15. **Compressed Gas Cylinders Secured.** More please see Appendix B Compressed Gas Cylinder Policy in General Laboratory Safety Manual.
16. **Minimize Trip Hazards.** Laboratories shall be maintained free of trip hazards. This includes items such as power cords on the floor, excessive equipment in the laboratory, and/or damaged flooring.

3.3.2 Chemical Inventory

Chemcial Inventory

All laboratories are required to keep an updated copy of their chemical inventory on file, which must be made available to EHLS upon request. Chemical inventory must be maintained and verified annually. For each hazardous substance on their inventory, below information must be indicated on the chemical inventory: **CAS number, Chemical name, and Quantity. Receipt Date is also required for peroxide forming materials such as sodium amide, diethyl ether, and isopropyl ether.** The Safety Data Sheets of the chemicals must be made readily available to all laboratory personnel.

What to Include in Your Chemical Inventory

You are required to include all hazardous materials in your inventory so the information is readily available to emergency responders and so that UH can provide accurate reports to federal and state agencies. The following examples are materials that required to be in the chemical inventory: all materials that are toxic, oxidizing, corrosive, reactive, carcinogenic, or flammable, as well as any liquids and gases under pressure including liquid nitrogen tanks and compressed air cylinders. However, many hazardous materials are excluded from the chemical inventory, per the table below. If you are unsure what to include, please contact EHLS.

What to include in your inventory	What not to include
All chemicals and chemical products (except those listed to the right)	Retail products used and stored in amounts and frequencies typical to ordinary household usage.
All compressed and liquefied gases	Etiologic agents (bacteria, viruses, select agents, and toxins)
Lubricants, fuels, and oils (motor oil, gasoline, diesel, vacuum pump oil)	Biological culture media, agar, serum proteins, albumin
Aerosol lubricants	Enzyme preparations
Paints including spray-paints	Non-hazardous buffers
Pesticides and biocides	Radioactive materials (unless mixed with hazardous chemicals)
	Pre-packed test kits for medical labs
	Commercially packaged drugs in solid, final form (tablets, pills) for direct administration
	Commercial food, drugs and cosmetics, covered by the FDA
	Materials to be used within 1-2 days ("working solutions")
	Hazardous waste

3.3.3 Housekeeping, Maintenance, and Inspections

Inspections

EHLS performs laboratory safety inspections routinely to ensure that adequate safety equipment is available and functioning, personal protection is available in use, chemicals are properly used and stored, SDSs are readily accessible and good housekeeping is being practiced. More frequent inspections may be performed by EHLS due to lab accidents, near misses, or unsafe lab practices and/or procedures. Follow-up inspections will be performed as necessary, to confirm completion of corrective actions.

During routine surveys conducted by EHLS, the safety reprensentative will talk with the Principal Investigator or Designee as well as laboratory personnel to ensure they have no specific safety concerns. If the Principal Investigator or Designee or laboratory personnel raise concerns, the EHLS safety representative will make every effort to address the issue either personally, or by way of an EHLS Safety Manager, or the EHLS Director.

Fire extinguishers shall be located inside all laboratories or, in some instances, a minimum of 75 feet from the laboratory. Extinguishers are inspected on a quarterly basis and maintained by the Fire Marshal's Office, which is part of Environmental Health and Life Safety (EHLS). Laboratory personnel shall routinely inspect for broken seals, damage, and low gauge pressure (depending on type of extinguisher). If problems are identified, repairs are requested by contacting EHLS at 713-743-5858.

Internal housekeeping and chemical hygiene inspections shall be conducted by the Principal Investigator or Designee at least quarterly. Refer to the format used in the EHLS inspections.

Repair

Facilities Management shall be contacted if safety equipment is malfunctioning.

- Non-Emergency Facility Service Requst: submit a service order or track work order status, log in to AccessUH and click on **Facility Request Self-Service (FIX-IT)**
- Any Emergency Facility Service Requst: call 713-743-4948 (FIX-IT)

Malfunctioning fume hoods must have the sash closed down completely and be marked “Do Not Use” if they are to be repaired. Contact EHLS for further information. To re-start an “Out of Service” fume hood, contact EHLS. Malfunctioning eyewashes and safety showers must be marked “Do Not Use". For repairs that havent been completed within five working days contact EHLS for assistance.

General Housekeeping

It is the responsibility of all laboratory personnel to ensure that the laboratory is maintained in a clean and orderly state. Excessive storage of equipment, supplies, and chemicals can pose various hazards to laboratory personnel and other building occupants.

Laboratories shall be maintained in such a manner where there is at least 36 inches of clearance between obstructions to exit from the laboratory into the corridor. The door from the lab to the corridor must remain closed at all times. The corridors must have a minimum of 48 inches of clearance and shall be maintained free of obstructions to ensure clear egress to the nearest stairwell in the event of an emergency. Many times, emergency safety equipment i.e. safety showers and eyewashes are also located in the main corridors and this equipment shall be maintained free of any obstruction.

3.3.4 Usage of laboratories

Work conducted in University of Houston is for research or instructional purposes. Work is laboratory scale in nature, and activities are conducted within the physical limitations of the laboratory facilities and safety equipment, especially local exhaust systems. EHLS shall be informed by the Principal Investigator or Designee when chemical usage falls outside of typical laboratory scale operations.

3.3.5 Other University Safety Programs

Laboratory personnel who work with biological agents and radiation sources or radiation producing devices, are subject to the requirements of the University’s Biological Safety and

Radiation Safety Programs, respectively. Further information on each is available at http://www.uh.edu/ehls/about/manuals/ .

4.0 Chemical Usage Procedures

4.1 Understanding and Minimizing Chemical Exposures

It is prudent to understand and minimize all chemical exposures by any route, and to observe good laboratory practices by using an exhast hood, wearing eye and hand protection, and a laboratory coat or apron. The cardinal rule for safety in working with hazardous substances is that all work with these materials in a laboratory shall be performed in such a way that they do not enter the body by any mode, including inhalation, injection, absorption or ingestion. Quantities of vapors or dust shall be prevented from entering the general laboratory atmosphere.

Under some circumstances, all chemicals can be hazardous. Even for substances of no known significant hazard, exposure must be minimized. Ffor work with substances that present special hazards, special precautions must be taken. One shall assume that any mixture will be more hazardous than its most hazardous component. In the research laboratory where new preparations are constantly being developed, it is especially wise to maintain at least the same level of safe practice in the disposal of chemical wastes and residues as in the actual preparative procedures. All substances of unknown hazard must be considered hazardous until proven otherwise.

Because few laboratory chemicals are without hazards, general precautions for handling all laboratory chemicals have been adopted in addition to specific guidelines. These general hazards for handling chemicals in the laboratory may be classified broadly as physical and health.

Physical hazards include those of fire, explosion or electric shock. Other physical hazards arise from high or low pressure, such as cylinders of compressed gases and experimental vessels, cryogenic equipment, furnaces, refrigerators and glass apparatus.

Health hazards are associated with their health effects and may be sub-classified as acute or chronic. Acute hazards are those capable of producing prompt effects (such as burns, inflammation, or damage to eyes, lungs, or nervous system). Some chemicals are extremely dangerous in this respect and even a small amount can cause death or severe injury very quickly. Other toxicological effects of chemicals may be delayed or develop only after exposure over long periods of time and are referred to as chronic hazards.

4.2 Chemical Hazards Types

4.2.1 Physical Hazards

FLAMMABILITY HAZARDS

A number of highly flammable materials (gases, liquids and solids) are in common use in campus laboratories. Flammable materials are substances that can ignite easily and burn rapidly. An UL-listed flammable storage cabinet must be used to store flammable materials. Quantities for storage are based on flammable class and location within the building. Flame-resistant laboratory coats must be worn when working with pyrophoric materials and/or with procedures where a significant fire risk is present. These materials can constitute a significant immediate threat and must be treated with particular care, even though the use of these materials is fairly common in the laboratory setting. Particular attention must be given to preventing static electricity and sparks when handling flammable liquids. (Based on the Global Harmonized System (GHS) adopted by OSHA (1910.106(a)(19)), flammable liquid means any liquid having a flashpoint at or below 199.4 °F (93 °C)).

REACTIVITY HAZARDS

Reactive and explosive substances are materials that decompose under conditions of mechanical shock, elevated temperature, or chemical action, and release large volumes of gases and heat. Some materials, such as peroxide formers, may not be explosive, but may form explosive substances over time. These substances pose an immediate potential hazard and procedures which use them must be carefully reviewed. These materials must also be stored in a separate flame-resistant storage cabinet or, in many cases, in laboratory grade refrigerator or freezer that are designed for flammable and reactive chemicals. Pyrophoric chemicals are a special classification of reactive materials that spontaneously combust when in contact with air and require lab-specific training. Flame-resistant laboratory coats must always be worn when working with pyrophoric chemicals.

4.2.2 Health hazards

OSHA uses the following definition for health hazards:

> The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes.

The major classes of "hazardous" and "particularly hazardous substances" and their related health and safety risks are detailed below and Chapter 5 Particularly Hazardous Substances (PHSs).

Corrosive Substances

As a health hazard, corrosive substances cause destruction of, or alterations in, living tissue by chemical action at the site of contact.

Major classes of corrosive substances include:

- Acids – e.g., sulfuric, nitric, and hydrochloric acids, hydrofluoric acid

- Bases – e.g., sodium hydroxide, potassium hydroxide and ammonium hydroxide
- Dehydrating agents – e.g., sulfuric acid, sodium hydroxide, phosphorus pentoxide and calcium oxide
- Oxidizing agents – e.g., hydrogen peroxide, chlorine and bromine.

Symptoms of exposure for inhalation include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea, and vomiting. For eyes, symptoms include pain, blood shot eyes, tearing, and blurring of vision. For skin, symptoms may include reddening, pain, inflammation, bleeding, blistering and burns. As a physical hazard, corrosive substances may corrode materials they come in contact with and may be highly reactive with other substances. It is important to review information regarding the materials they may corrode, and their reactivity with other substances, as well as information on health effects. In most cases, these materials must be segregated from other chemicals and require secondary containment when in storage, specialty hoods, and exhaust ducting.

Irritants

Irritants are defined as non-corrosive chemicals that cause reversible inflammatory effects on living tissue by chemical action at the site of contact. A wide variety of organic and inorganic compounds, including many chemicals that are in a powder or crystalline form, are irritants. The most common example of an irritant may be ordinary smoke which can irritate the nasal passages and respiratory system. Consequently, eye and skin contact with all laboratory chemicals must always be avoided. Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.

Sensitizers

A sensitizer (allergen) is a substance that causes exposed people to develop an allergic reaction in normal tissue after repeated exposure to the substance. Examples of sensitizers include diazomethane, chromium, nickel, formaldehyde, isocyanates, arylhydrazines, benzylic and allylic halides, and many phenol derivatives. Sensitizer exposure can lead to all of the symptoms associated with allergic reactions, or can increase an individual's existing allergies.

4.3 Hazardous Chemical Classification Systems

Chemical classification systems are designed to communicate hazards. The three most widely used classification systems are the OSHA Globally Harmonized System for Classifying and Labeling Chemicals (implemented under the OSHA Hazard Communication Standard), the National Fire Protection Association (NFPA) system of classifying the severity of hazards, and the Department of Transportation (DOT) hazard classes. These classification systems are used by chemical manufacturers when creating safety data sheets and chemical labels, therefore it is important that University of Houston laboratory personnel understand the basic elements of each classification system. These classification systems are provided in Appendix 2.

4.4 Controlling Chemical Exposures

Many chemicals can cause immediate health problems as well as long-term health effects. Examples include carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes. Hazardous chemicals (such as flammable liquids, compressed gases, and unstable water-reactive materials) can also pose inherent physical dangers.

There are three major routes of entry for a chemical to enter the body: inhalation, skin and eye contact, and ingestion. Three types of controls for prevention of these various routes of entry include: elimination and substitution, engineering controls, personal protective equipment and administrative controls. Each route of entry a chemical can take to enter the body can be controlled in a number of ways, as explained below.

4.4.1 Inhalation Hazards

Inhalation of chemicals is the most common route of entry a chemical can take to enter the body. To avoid significant inhalation exposures, elimination and substitution are the best options to eliminate or minimize hazards. For example, substituting a less volatile or a less toxic chemical, or substituting a liquid or solid chemical for a gaseous one are the best means of control. If substitution is not practical, engineering control, such as ventilation, shall be used to lessen the chance of overexposure. The use of well-functioning local exhaust ventilation such as chemical fume hoods, vented glove boxes and other local exhaust systems are often required to minimize exposure to hazardous chemicals. Dilution ventilation may be used to reduce exposure to non-hazardous nuisance odors. For extremely toxic chemicals such as those classified as poisonous gases by State or Federal Department of Transportation (e.g., arsine, phosgene) the use of closed systems, vented gas cabinets, fail-safe scrubbing, detection or other stricter controls may be required.

Administrative controls can be utilized to reduce the risk of overexposure to hazardous chemicals. Some examples of administrative controls include:

- minimization of exposure time for individual laboratory personnel;
- restricted access to an area where a hazardous chemical is used;
- allowing a process that emanates nuisance odors to be done only after typical office hours, when most of the staff in the building have gone home; and,
- proper signage on laboratory doors to indicate special hazards within, a list of laboratory personnel who will be contacted in the event of an emergency, and appropriate telephone numbers. Call EHLS for assistance.

Finally, if engineering and administrative controls are not an option, the use of personal protective equipment (PPE) is a last resort to reduce inhalation exposures. If respirators are worn by laboratory personnel, requirements of the OSHA Respiratory Protection Standard (29 CFR 1910.134) must be met. This standard requires training on the proper use of respirators, medical surveillance to ensure the user is capable of wearing a respirator, and fit testing to ensure that the respirator fits properly. Laboratory personnel or his/her Principal Investigator or Designee shall

contact EHLS in the event that respiratory protection is needed to control exposures to hazardous chemicals. Annual fit testing will be required for continuous use.

4.4.2 Skin/Eye Contact Hazards

To reduce the risk of a chemical entering the body via skin and eye contact, substitution and appropriate engineering controls, shall be used as described above in "Inhalation Hazards." The more obvious means of preventing skin and eye contact is the wearing of personal protective equipment such as eye protection, face shields, gloves, appropriate shoes, lab aprons, lab coats, and other protective equipment appropriate to the hazard. Since the chemical resistivity of the different types of protective equipment varies significantly, the Principal Investigator or Designee shall consult SDS/MSDS of the chemical, glove manufacture or OSHA recommendation to ascertain that the protective equipment material is resistant to the chemical being protected against.

Administrative controls can be utilized to reduce skin/eye contact. Some examples of administrative controls include enforcement of policies pertaining to skin and eye protection, and discarding or repairing cracked or broken glassware.

4.4.3 Ingestion Hazards

Ingestion of chemicals is the least common route of entry into the body. Laboratory personnel can easily ingest chemicals into the body via contaminated hands if they are not washed prior to eating or smoking. Also, introducing contaminated objects (writing tools, cell phones) and/or hands in the mouth is another form of ingestion. Use engineering controls, such as isolating the hazardous substance so that minimal contact is required (e.g., use glove box), to help prevent exposures. Administrative controls such as restricting mouth pipetting, encouraging good personal hygiene, and designating a well-marked non-chemical area where eating, drinking and the application of cosmetics are permitted, is also beneficial in preventing chemical exposures via ingestion. Personal protective equipment, such as gloves, must be used as required.

4.5 Labelling and Signage

All University of Houston laboratory personnel who work with chemicals must be familiar with conventions used for hazard communication via signs and labels. This information is provided in EH06: General Laboratory Safety Training. Labeling requirements for all hazardous substances are summarized as follows:

Manufacturers are required to label every chemical container with hazard information that includes chemical name, physical and health hazard information, and name of manufacturer. These labels relay valuable information that can assist in hazard evaluation and control, and cannot be removed or defaced from the original container unless the contents have been altered or removed. Labels must be legible, in English, and prominently displayed. It is recommended that each bottle also be dated when received and when opened to assist in determining which chemicals are expired and require disposal.

Secondary use containers must be labeled with the identity of the substance and appropriate hazard warnings at a minimum. It is recommended that secondary use containers be labeled with the substance name, type of hazard, name of laboratory personnel who prepared the container, and date of preparation.

New synthesized compounds by laboratory operations must be labeled with the chemical name, name of laboratory personnel who prepared the container, date of preparation and appropriate hazard warnings based on the knowledge of the chemical and physical properties of that substance.

Peroxide-forming materials (e.g., ethers) must be dated when opened and disposed of through EHLS within one year from the date of opening or by the manufacturer's expiration date, whichever occurs first. Consult the manufacturer's SDS to determine. These chemicals can degrade to form shock sensitive, highly reactive compounds and must be stored and labeled very carefully.

Laboratories shall prominently post below signage listed on EHLS website:

1. Notice To Emplyees HAZCOM Poster
2. No eating or drinking sign

3. Location signs for safety showers, eye washes, fire extinguishers, spill response kits, and first aid equipment
4. Chemical spill response procedures
5. Emergency evacuation plan
6. Emergency contact information
7. Warning signs at areas or equipment where special or unusual hazards exist

Radioactivity work areas, laboratories and containers of radioactive materials must be posted with appropriate warning signs. (See Radiation Safety Manual) Areas where human blood or other potentially infectious materials are stored or used must bear the universal biohazard symbol. Researchers working with or storing biosafety level 2 or higher organisms shall utilize the universal biohazard warning. Appropriate locations for biohazard signs include laboratory entrance, incubator, refrigerator, and waste containers. (See Biological Safety Manual)

Emergency postings shall also be placed on the laboratory electrical panel and emergency gas shut off valve. These two emergency cut-offs are utilized in emergency situations and shall never be obstructed with equipment or storage.

EHLS prepares and posts laboratory door safety signs outside each laboratory. Contact EHLS if the information on your door sign changes or needs to be updated.

4.6 Prior Approval for the Acquisition and Use of Hazardous Substances

The Principal Investigator or Designee is responsible for obtaining approval for the acquisition and use of toxic chemical agents. Certain materials including highly explosive or toxic chemical agents, radioactive materials and certain biological agents require prior approval from the respective safety committee at various levels. Questions concerning the need for approvals shall be directed to EHLS.

4.7 Procurement of Chemicals

EHLS shall be contacted for the requisitions with hazardous chemicals listed on "**Addendum B for Requisitions**". (http://www.uh.edu/administration-finance/purchasing/Forms/). The completed Addendum B, purchase requisition, and related paperwork (vendor quote, etc.) must be scanned and emailed to ehs@uh.edu for EHLS approval. No container shall be accepted without an adequate identifying label. Delivery must be refused for leaking containers.

EHLS shall also be contacted in advance of any acquisition of chemicals that will not be purchased but are to be transferred to the University of Houston from another university or organization.

4.8 Handling, Storage & Segregation of Chemicals

Hazards associated with various chemicals and gases vary widely. Understanding the hazards associated with a compound and minimizing the quantity used and stored in the laboratory will decrease the chance of injury. In order to minimize the presence of hazardous materials at the university, chemicals must be ordered in the smallest quantity needed to conduct the work. Large quantities are not allowed (55 Gal Drum) unless approved by EHLS before purchasing.

General Guidelines for All Laboratory Chemical Storage:

General Guidelines For All Laboratory Chemical Storage
Date all chemicals on receipt and keep an up to date chemical inventory. EHLS requires an updated hazardous chemical inventory from each PI annually.
Label all storage areas and cabinets to identify the hazardous nature of chemicals stored within.
Ensure all chemicals are properly identified and labeled before they are stored.
All secondary labels must include the chemical name, date, and the user's name or initials.
Store all chemicals in a cool and dry location with caps or lids tightly closed.
NO CHEMICAL RESIDUE SHOULD BE ON THE OUTSIDE OF ANY CONTAINERS.
Chemical containers must not be stored on floors or stacked on top of each other.
Store and arrange chemicals in compatible families rather than in alphabetical order. Alphabetical order is acceptable within compatible storage families.
Always purchase highly hazardous materials in the smallest quantities possible. They must also be isolated and properly labeled.
Do not store hazardous chemicals on bench tops.
Ensure that all containers are not corroded, broken, rusted, or leaking.
DO NOT STORE CHEMICALS EXCEPT FOR CLEANERS UNDER SINKS.

4.8.1 Chemical handling and labelling

Proper PPE must be doned during any chemical handling process. Use secondary containment when transporting chemicals by placing the chemical being transported inside a protective container. For example, use polycoated bottles or bottle carriers for transporting chemicals that are in regular glass containers. Close caps securely and avoid storing chemical containers in hard to reach areas. Pour chemicals carefully, and never add water to concentrated acid or base. Metal containers and non-conductive containers (e.g., glass or plastic) holding more than five gallons must be grounded when transferring flammable liquids.

Check the integrity of containers. Ensure that the container used is compatible with the chemical, for example hydrofluoric acid must not be stored in glass container.

Make sure all labels are legible. Label all secondary use containers with the chemical name (as it appears on the original label or SDS) and appropriate hazards at a minimum. (More information see 4.5 Labelling and Signage) Health hazard warning information shall include the target organs that may be affected and any of the following terms that are appropriate: carcinogen, acutely toxic, reproductive toxin, irritant, corrosive, sensitizer, etc. Physical hazard warning information shall include any of the following terms that are appropriate: flammable liquid, compressed gas, explosive, organic peroxide, oxidizer, pyrophoric or water reactive. Date all peroxidizable (e.g. diethyl ether) and other chemicals that may become unstable over time; test and/or dispose of them when appropriate.

4.8.2 Chemical storage and segregation

Chemicals must be stored by compatibility, not by alphabetical arrangement. Separate chemicals into organic and inorganic families and then into related and compatible groups. Suggested chemical storage schemes and compatibility lists can be found in a number of lab safety resources available from the National Institute of Occupational Safety and Health (NIOSH) website and this Chemical Hygiene Plan. A quick and very general rule of thumb is to separate flammables from oxidizers (including gases as well as liquids), acids from bases, and reactives from air or water. Chemicals shall never be stored on the floor. For example, hydrogen peroxide must be separated from organics; air/water reactives must be kept dry and cyanides must be stored away from acids. Storage of all laboratory chemicals shall follow the recommendations outlined in Appendix 3. Chemical Segregation and Incompatibilities Guidelines.

Stockrooms/Storerooms: Hazardous substances in storage must be segregated by hazard categories, following manufacturer recommendations. Containers of Particularly Hazardous Substances (PHSs) shall be placed in secondary containment. Stored chemicals shall be examined periodically (at least annually) for replacement, deterioration, and container integrity. Stockrooms and storerooms must not be used as preparation or repackaging areas.

Laboratory Storage: Storage in laboratories will be performed as follows:

- Chemicals must be stored so incompatible chemicals are separated. Compatibility information is available on the chemical's Safety Data Sheet (SDS).
- Every chemical must be assigned to a definite storage place and must be returned to that place after each use. Do not store materials on top of high cabinets where they will be hard to reach and see.
- Chemical storage in hoods and on bench tops are never allowed.
- Chemicals must never be stored on the floor, not even temporarily, to greatly reduce the chance that the chemical is knocked over by someone who does not see the container.
- Chemical bottles must be properly placed on a flat surface instead of being piled up. Purchase only what is needed.
- Chemicals must avoid exposure to heat or direct sunlight. This may lead to the deterioration of storage containers and labels, as well as the degradation of the chemicals.
- Chemicals must never be stored (except cleaners) under sinks.
- Volatile toxic substances shall be stored in storage cabinets adequate to the purpose. If volatile substances are temporarily stored in a hood for current use, other uses of the hood shall be restricted to activities compatible with the chemical and physical properties of the

chemicals being stored or used. When volatiles must be stored in a cooled atmosphere, refrigerators or cold rooms designed for this purpose must be used.

- A UL-listed flammable storage cabinet must be used to store flammables. Quantities for storage are based on flammable class and location within the building, see NFPA 30, *Flammable and Combustible Liquids Code*, NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals* for specific quantities. Flammable liquid means any liquid having a flashpoint at or below 199.4 °F (93 °C) (29 CFR 1910.106(a)(19)). When flammable liquids must be stored at reduced temperature, an explosion-proof refrigerator or certified flammable material storage refrigerator, where ignition sources are isolated from the inside space, will be required.
- Large quantities (> 1L) of flammable liquids shall be stored below eye level.
- Chemical inventory must be maintained and verified annually.
- Periodic cleanouts must be conducted to prevent accumulating unnecessary chemicals. Out-dated, expired, unknown chemicals must be promptly disposed of. Many materials, as they age, become unstable, possibly forming explosive by-products or undergoing rapid and violent decompositions. Other materials simply lose purity as contaminants are introduced or residues form. Chemicals that may no longer be used, that are of questionable purity, or that are past their expiration dates must be removed from the laboratory by submitting an on-line pickup request from EHLS.
- New construction must follow NFPA 45 for guidelines on flammable and combustible liquid storage. UH Fire Marshal's Office shall be contacted for further assistance.

Specific Storage Requirements
(More please see Appendix 3: Chemical Segregation and Incompatibilities Guideline)

Acids

- Segregate inorganic acids from organic acid and flammable and combustible materials.
- Segregate acids from bases.
- Segregate acids from active metals such as sodium, potassium, and magnesium.
- Store acetic acid as a flammable liquid. This is an organic (carboxylic) acid that will react if it comes in contact with an oxidizing acid. Keep acetic acid in flammable safety cabinet also but also be kept in secondary containment in case of a spill.
- Nitric acid and hydrochloric acid may be stored in the same corrosive storage cabinet, but they must be kept in separate secondary containment. These can combine to form chlorine and nitrosyl chloride gases—both are toxic.
- Segregate acids from chemicals that could generate toxic or flammable gases upon contact, such as sodium cyanide, iron sulfide and calcium carbide.
- If hydrofluoric acid is in storage or in use, EH08: Hydrofluoric Safety Acid Lecture from EHLS will be mandatory training for all lab workers. . Contact EHLS for more information.
- Storage and use of perchloric acid shall follow the "UH Guideline for Perchloric Acid Usage and Storage" in Appendix 6.

Bases

- Segregate bases from acids, metals, explosives, organic peroxides and easily ignitable materials.

- Do not store aqueous sodium and potassium hydroxide solutions in aluminum drip trays. These will corrode aluminum.

Flammable liquids

- Store in approved safety cans or cabinets.
- Segregate from oxidizing acids and oxidizers.
- Keep away from any source of ignition: heat, sparks, or open flames.
- Never store flammable liquids in a domestic refrigerator. Only certified flammable liquid refrigerators can be used to store flammable liquids.

Oxidizers

- Keep away from flammable and combustible materials.
- Keep away from reducing agents such as zinc, alkali metals, hydrazine, oxalic acid, and formic acid.

Cyanides

- Segregate from aqueous solutions, acids and oxidizers.

Unstable Explosives

- Shall not be stored in the laboratory. Typical example is **Dry Picric Acid**. Contact EHLS for further assistance.

Pyrophoric or Water-Reactive Substances

- If in original container store in a cool, dry place, making provisions for an airtight seal.
- Store in a glove box after the material has been opened.
- More please see Appendix 8. UH Guideline for Pyrophoric/Water-reactive Chemicals Usage and Storage.

Nanomaterials

- Please see Appendix 7. UH Guideline for Nanomaterials.

Light-Sensitive Chemicals

- Store in amber bottles in a cool, dry, dark place.

Peroxide-Forming Chemicals

- Store in the flammable cabinet with the other flammable materials.
- Peroxide-forming materials must be dated when opened and disposed of through EHLS within one year from the date of opening or by the manufacturer's expiration date whichever occurs first. Consult the manufacturer's SDS to determine.
- Segregate from oxidizers and acids.

Organic Peroxides

- store away from flammable materials.

Particularly Hazardous Substances (Solids)*

- Store in general chemical storage, segregated from incompatibles. Ideally they would be stored separately from other chemicals and easily identifiable within the laboratory. More please see Chapter 5.

Particularly Hazardous Substances (Liquids)*

- The organic solvents and solutions (such as formaldehyde and chloroform) shall be stored in a flammable cabinet. Inorganic solutions & compounds shall be stored in general storage in secondary containment. More please see Chapter 5.

Low Toxicity Materials / Irritants

- Store in general chemical storage.

* Particularly Hazardous Substances refer to select carcinogens, acutely toxic chemicals, reproductive toxins and chemicals known to have undesirable biological effects. More please see Chapter 5.

4.8.3 Cylinder handling and storage

Cylinder storage. Cylinders must be stored in well-ventilated areas with their protective caps screwed on and the cylinder secured (e.g chained down) to reduce the chance of the cylinder being knocked over. For assistance in securing gas cylinders, call EHLS at 713-743-5858. Do not store cylinders near heat or high traffic areas. Do not store flammables and oxidizers together. For example, carbon monoxide (CO) and nitrogen dioxide (NO_2) can not store together. Do not store empty and full cylinders together. Storage of large quantities of cylinders must be done in an approved gas cylinder storage area. All cylindes in a lab are considered in use.

Cylinder handling. Use appropriate handcarts to move cylinders. Cylinders must be capped and secured to the cart during transport. Highly toxic gases shall not be moved through the corridors and passenger elevators, particularly during business hours. Always consider cylinders as full and handle them with corresponding care. EH26: Compressed Gas Cylinder Safety training is mandatory for all UH laboratory personnel who handle compressed gases.

4.9 Transport of Chemicals

The following safety precautions must be taken for chemical transport:

- Chemicals must be transported upright in safety containers with secondary containment, or on a wheeled cart with a design capable of containing leakage or spillage and negotiating uneven surfaces (e.g. expansion joints or floor drains) without tipping the chemical container or cart.
- Chemicals shall be transported on freight elevators where possible.
- Chemical containers must be sealed during transport.
- Cylinders must be strapped to a hand truck specifically designed for that purpose and cylinder cover caps must be in place.

5.0 Particularly Hazardous Substances (PHSs)

5.1 Definition

The Occupational Safety & Health Administration's (OSHA) Laboratory Standard (29 CFR 1910.1450 (e) (3) (viii), requires that provisions be made for employee protection for work with particularly hazardous substances. These include select carcinogens, reproductive toxins, and acutely toxic substances.

"Particularly Hazardous Substances" are defined as belonging to one of three groups.

1. Select carcinogens, acutely toxic chemicals, reproductive toxins and chemicals known to have undesirable biological effects.

2. Chemicals for which reliable toxicity information is not available, but are highly suspected to be a PHS because of their similarity in chemical structure or function to known toxic agents.

3. Chemicals which are explosive or otherwise violently reactive, such as pyrophorics and water-reactive materials.

Particularly Hazardous Substance (PHS)	**Definition**
Select carcinogens	Any substance that meets at least one of the following criteria: • Regulated by OSHA as a carcinogen or; • Listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) or; • Listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer (IARC) Monographs or; • Listed in either Group 2A or 2B by IARC or under the category "reasonably anticipated to be carcinogens " by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria: i) After inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m^3 ii) After repeated skin application of less than 300 mg/kg of body weight, per week or iii) After oral dosages of less than 50 mg/kg of body weight per day

	Select carcinogens are designated by one of the following H codes: **H350** May cause cancer **H351** Suspected of causing cancer
Reproductive Toxins	Chemicals that affect the reproductive capabilities including causing chromosomal damage (mutations) and adverse effect on fetal development (teratogenesis). **Reproductive toxins** are designated by one or more of the following H codes: **H340** May cause genetic defects **H341** Suspected of causing genetic defects **H360** May damage fertility or the unborn child **H361** Suspected of damaging fertility or the unborn child **H362** May cause harm to breast-fed children
Acute toxicity	The ability of a chemical to cause a harmful effect after a single exposure. Acutely toxic chemicals are defined by the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) **Categories 1 and 2**. The corresponding parameters for assessing the risk of acute toxicity of a chemical are its LD50 and LC50 values meet the following criteria: • Chemicals with an oral LD50 in rats <50mg/kg • Chemicals with a skin contact LD50 in rabbits <200mg/kg • Chemicals with an inhalation LC50 in rats <200ppm/per hour • Chemicals with an inhalation LC50 in rats <2.0 mg/L or 2000 mg/m^3 Acutely toxic chemicals may also have other hazardous properties in addition to acute toxicity. Safety use requires assessing all potential hazards. **Acutely toxicity** are designated by one or more of the following H codes: **H300** Fatal if swallowed (Category 1 or 2) **H310** Fatal in contact with skin (Category 1 or 2) **H330** Fatal if inhaled (Category 1 or 2)

Other definitions:

"Lethal Dose 50 (LD50)" is defined as the amount of a chemical that when ingested, injected, or applied to the skin of test animals under controlled laboratory conditions will kill one-half (50%) of the animals.
"Lethal Concentration 50 (LC50)" is the concentration of the chemical in air that will kill 50% of the test animals exposed to it.

"Designated areas" are areas that may be used for work with particularly hazardous substances. A designated area may be the entire laboratory, an area of a laboratory, or a device such as a laboratory hood or glove box.

PHS List on Appendix 4 is also provided to help you comply with the OSHA Hazardous Chemicals in Laboratory Standard (Code of Federal Regulations, Title 29, Part 1910.1450).

5.2 Responsibilities

It is the responsibility of the Principal Investigator or Designee to ensure that PHS determination is conducted on all existing chemical inventories and on all future chemical purchases. Furthermore, prior to beginning work with a PHS, or once the PHS determination is made, Principal Investigator or Designee shall complete a laboratory-specific PHS Standard Operating Procedures (PHS SOP). Principal Investigator must ensure that laboratory personnel are trained, understand, and implement the procedures as directed in the SOP.

All laboratory personnel approved to work with a particularly hazardous substance shall be trained by Principal Investigator or Designee and strictly comply with that cautions and procedures. Contact Environmental Health and Life Safety (EHLS) for assistance.

5.3 PHS SOP

The purpose of the PHS SOP (templates see Appendix 5) is to ensure that all laboratory personnel are adequately trained and familiar with PHS's chemical/physical properties, health hazard information and toxicity data before the use of them. Procedures for containment, storage, and waste management shall be described in detail. Safety precautions shall be addressed including: assignment of designated area, personal protective equipment, engineering controls, first aid procedures and spill procedures.

In addition to the general safety guidelines in Section 3.3 and throughout the Plan, special precautions are needed when handling these types of chemicals. A minimum set of guidelines that must be followed is listed below. The Principle Investigator or Designee must ensure that these and other precautions designed to minimize risk of exposure to these substances are taken.

- Quantities of these chemicals used and stored in the laboratory must be minimized, as shall their concentrations in solutions or mixtures.

- Work with carcinogens, reproductive toxins and acutely toxic chemicals must be performed within a functioning chemical fume hood, ventilated glove box, sealed system, or other system designed to minimize exposure. The exhaust air from the ventilation systems may require scrubbing before being released into the atmosphere. In all cases, work with these types of chemicals shall be done in such a manner that the OSHA permissible exposure limits or similar standards are not exceeded.

- Compressed gas cylinders that contain acutely toxic chemicals must be kept in ventilated

gas cabinets. The toxic gases are defined as gases that cause significant acute health effects at low concentrations, have a National Fire Protection Association (NFPA) health rating of 3 or 4, have low occupational exposure limits, or are pyrophoric.

- The ventilation efficiency of the designated hood, glove box or gas cabinet, and the operational effectiveness of mechanical and electrical equipment used to contain or manipulate these special substances must be evaluated periodically by authorized trained personnel or manufature designated personnel at intervals determined by manufactures. The interval of evaluating systems may vary depending on manufactures' specification.

- Each laboratory utilizing these substances must designate an area for this purpose and must sign or mark this area with an appropriate hazard warning. The designated area may be an entire laboratory, an area of the laboratory or a device such as a fume hood or glove box. The designated area shall be marked with a DANGER, specific agent, AUTHORIZED PERSONNEL ONLY or comparable warning sign.

- All laboratory personnel who work in a laboratory that has an area designated for use with carcinogens, reproductive toxins and acutely toxic chemicals must be trained about the deleterious effects of these substances as well as signs and symptoms regarding exposure to these substances, whether or not they actually work with the substance themselves. Training to ensure the safe handling and storage of these substances is required for those who use these materials. This training is the responsibility of the Principal Investigator or Designee and must be done prior to the use of any of these materials.

- Laboratory personnel working with these chemicals must have access to appropriate protective equipment and must be trained on how to properly utilize the safety equipment.

- Detection and/or monitoring equipment will be required in laboratories where chemicals (especially poisonous gases) with a high degree of acute toxicity, high flammability are utilized. The monitoring equipment must be connected to the fire alarm system to notify the occupants of the building. Monitoring equipment must be maintained and tested according to manufactor specifications. Any problems must be corrected as soon as possible or remove PHS from lab.

- All wastes contaminated with these substances must be collected and disposed of in a timely manner and appropriately as outlined in the Regulated Waste Manual. For special disposal information, call EHLS at 713-743-5858. If possible and as soon as practical, waste products shall be destroyed by a suitable, generally acceptable chemical procedure to lessen or eliminate their toxicity.

- The designated working area shall be thoroughly and appropriately decontaminated and cleaned at regular intervals determined by Principal Investigator or Designee. The interval may be as short as one day or as long as six months depending upon the frequency of usage and level of hazard.

- Special precautions to avoid release and exposure to highly toxic chemicals, carcinogens

and reproductive toxins must be utilized. For instance, volatile substances must be kept cool and contained; gases must have properly functioning valves, check valves, regulators, containment which can withstand pressure buildup, and appropriate piping; and dispersive solids must be kept in closed containers, used in places with minimum air currents, and appropriate contact materials must be used to avoid static discharge.

- Emergency response planning for releases or spills must be clearly outlined in PHS SOP by the Principal Investigator or Designee and included in the training of the laboratory personnel and others who may be affected in the building. EHLS can be contacted for assistance.

5.3.1 Principal Investigator approval

The written PHS SOP must be approved and signed by the Principal Investigator before work with PHS chemicals may begin. The entire PHS SOP shall be reviewed by the Principal Investigator or Designee for accurancy. These procedures shall be reviewed and changed at the time of any process change. Consultation with Environmental Health and Life Safety is recommended to ensure that procedures and safety precautions are adequate. The lab-specific PHS SOP, including the signature page with signatures by all involved personnel must be maintained by the Principal Investigator or Designee, and be submitted to EHLS either electronically via the ehs@uh.edu or hard copy upon request.

5.3.2 Lab personnel training

Laboratory personnel must be trained, understand, and implement the procedures as directed in the SOP. Additional employees may be added to an existing SOP, or an existing SOP may be approved for use in another laboratory. In these cases, the protocol form must still be reviewed by the Principal Investigator or Designee and approved for use for each additional employee. Copies of the completed SOPs with signuature page (training document) shall be forwarded to EHLS upon request.

6.0 Response to Non-compliance

Discrepancies discovered during routine inspection will be addressed in the following manner.

Step One - Verbal Notification:

If, during a routine evaluation or inspection, a problem involving chemical safety procedures is observed, a verbal violation will be provided. If upon receipt of a verbal violation, the laboratory personnel takes immediate steps to correct the problem, then no further response regarding the discrepancy will be requested.

Any laboratory personnel who is not wearing proper attire or PPE will be asked to leave the laboratory immediately by EHLS until the situation is corrected.

Step Two - Written Notification

Following the inspection a written summary of the findings along with violations to address any remaining concerns, if applicable, will be sent to the PI responsible for the laboratory. The PI will then be requested to respond in writing within 15 days and describe his/her plan to address any unresolved safety violations.

Step Three - Second Written Notification

A list of discrepancies will be maintained by the Environmental Health and Life Safety Department Staff and a follow-up will be conducted within 30 days of the inspection to determine if corrective actions were taken.

Step Four - Follow-up Inspection

If the follow-up inspection reveals that the same discrepancy exists, notification of this situation will be sent to both the PI and the Department Chair. The Director of EHLS, depending on the nature of the concern, may present the issue to the appropriate Dean and other senior administration officials.

Any procedure causing a high or unacceptable exposure risk or IDLH, (immediately dangerous to life or health) to employees or laboratory personnel will be suspended immediately by EHLS without regard to the above procedure.

7.0 Medical Consultation

An opportunity to receive medical consultation shall be provided under the following circumstances: if an employee develops any symptoms thought to arise from chemical overexposure; after an event such as a major spill, leak or explosion which may have resulted in an overexposure; or, if an overexposure is identified as the result of an evaluation of the facility by EHLS.

These suspected or actual exposures requiring medical evaluation shall be treated as a regular Worker's Compensation claim. A “Supervisor’s First Report of Injury” form must be filled out and signed by the supervisor and submitted to a the Risk Manager’s office within 24 hours.

Additional employee injury forms are required to be completed by the employee and filed with Risk Management within 48 hours.

Following notification of overexposure, arrangements for an appropriate medical examination by a medical provider within the University’s certified medical network, (Injury Management Organization) must be completed before the exposed individual may return to work. If an emergency situation exists, treatment at any hospital emergency center will be accepted. Any medical examination required shall be provided without cost to the employee provided the

University's workers compensation administrator determines the exposure is directed related to the employee's employment.

Appendix 1. UH Laboratory Dress Code Policy

UNIVERSITY of HOUSTON
ENVIRONMENTAL HEALTH & LIFE SAFETY

UH Laboratory Dress Code Policy

Standard Practice

The University of Houston Chemical Hygiene Plan states in Section 3.2 "**Attire.** Legs and feet must be covered by closed-toe shoes, long pants or skirts which fully cover the legs (no sandals, open-toed shoes, or shorts), long hair must be confined and loose clothing and jewelry must be secured before beginning work. Wear a properly fastened lab coat or apron specific for the hazards of the procedures performed in the laboratory. This includes, but is not limited to, using flame resistant clothing for use with pyrophorics, acid resistant protection when working with acids (especially HF or other strong acids), and protective items when working with hot or cold materials. The Principal Investigator or Designee is responsible for enforcing the protective clothing needed."

Purpose and Scope

This policy applies to all Laboratory Personnel while working in a laboratory at the University of Houston. All leadership and management representatives of the department/area have the authority and responsibility to enforce this policy.

Definitions

- Closed-toe shoes are shoes that completely cover the feet and are well secured on to the foot.
- Long pants are trousers, slacks or pants that extend from the Laboratory Personnel's waist to the top of their shoes
- Long skirts are skirts or skorts that extend from the waist to the top of their shoes
- Lab coats are lightweight coats worn for the purpose of protecting Laboratory Personnel's skin and clothing from chemical splashes. The fiber content of a laboratory coat must be appropriate for the chemicals in use. Use all-cotton lab coats when working with flammable materials. Use flame-resistant (FR) lab coats when working with pyrophorics.
- Long hair is any length of hair that could become entangled in equipment or dangle into chemicals or flames during work.

- Loose clothing is items such as loose-fitting sleeves, scarves, sweatshirt drawstrings and other clothing items that could become entangled in equipment or dangle into chemicals or flames during work.
- Jewelry are items such as necklaces, earrings, bracelets or watches that could become entangled in equipment or dangle into chemicals or flames during work.

UH LABORATORY DRESS CODE TRAINING RECORD*

PI Acknowledgement			
Name:		E-Mail:	
Signature:		Date:	
Office Phone:		Cell Phone:	

Trained Laboratory Personnel

"I have read and understand the Laboratory Dress Code. I agree to fully adhere to its requirements. By signing below, I also acknowledge that I have received hands-on training for the appropriate lab dress."

Last	First	PSID	Email	Signature	Date

*This document, including the signature page with signatures by all involved personnel shall be maintained by the Principal Investigator or Designee, and be submitted to EHLS either electronically via the ehs@uh.edu or hard copy upon request.

Appendix 2. Hazardous Chemical Classification Systems

Appendix 2. Hazardous Chemical Classification Systems

1. Globally Harmonized System for Classifying Chemicals

The Globally Harmonized System (GHS) is a world-wide system adopted by OSHA for standardizing and harmonizing the classification and labeling of chemicals. The objectives of the GHS are to:

- Define health, physical, and environmental hazards of chemicals;
- Create classification processes that use available data on chemicals for comparison with the defined hazard criteria (numerical hazard classification is based on a 1- 5 scale, 1 being the most hazardous and 5 being the least hazardous); and
- Communicate hazard information, as well as protective measures, on labels and Safety Data Sheet (SDS), formerly known as Material Safety Data Sheets (MSDS).

1.1 Safety Data Sheets

The SDS provides comprehensive information that is imperative for the safe handling of hazardous chemicals. Laboratory personnel shall use the SDS as a resource to obtain information about hazards and safety precautions. SDSs cannot provide information for hazards in all circumstances. However, the SDS information enables the employer to develop an active program of worker protection measures such as training on hazard mitigation. Chemical manufacturers are required to use a standard format when developing SDSs. The SDS will contain 16 headings which are illustrated in Table 1.

Table 1 – GHS Required Section of a Safety Data Sheet

1.	Identification of the substance or mixture and of supplier	**9.**	Physical and chemical properties
2.	Hazards Identification	**10.**	Stability and reactivity
3.	Composition/information on ingredients	**11.**	Toxicological information
4.	First aid measures	**12.**	Ecological information
5.	Firefighting measures	**13.**	Disposal considerations
6.	Accidental release measures	**14.**	Transport considerations
7.	Handling and storage	**15.**	Regulatory information
8.	Exposure controls/personal protection	**16.**	Other information

1.2 Chemical Labeling

The GHS standardized label elements, which are not subject to variation and must appear on the chemical label, contain the following elements:

- Symbols (hazard pictograms) are used to convey health, physical and environmental hazard information, assigned to a GHS hazard class and category;
- Signal Words such as “Danger" (for more severe hazards) or "Warning" (for less severe hazards), are used to emphasize hazards and indicate the relative level of severity of the hazard assigned to a GHS hazard class and category;
- Hazard statements (e.g., “Danger! Extremely Flammable Liquid and Vapor”) are standard phrases assigned to a hazard class and category that describe the nature of the hazard; and
- Precautionary statements are recommended measures that shall be taken to minimize or prevent adverse effects resulting from exposure to the hazardous chemical.

The GHS also standardizes the hazard pictograms that are to be used on all hazard labels and SDSs. There are 9 pictograms that represent several defined hazards, and include the harmonized hazard symbols which are intended to convey specific information about each hazard. Figure 1 illustrates these GHS hazard pictograms.

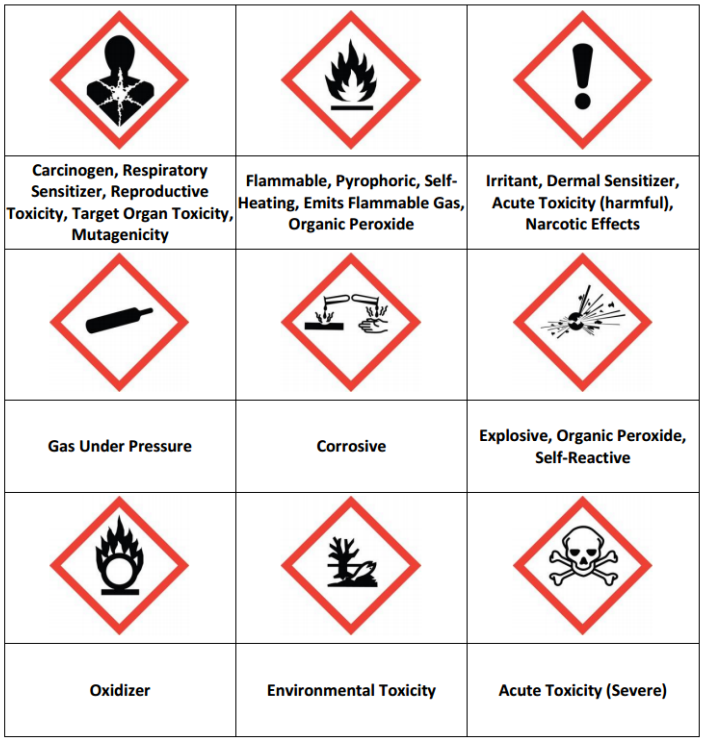


Figure 1 – GHS Hazard Pictograms

GHS labeling requirements are only applicable to chemical manufacturers, distributors, and shippers of chemicals. GHS labeling requirements are not required for chemicals being stored in a laboratory. However, since most chemicals stored in the laboratory have been purchased from a chemical manufacturer, the GHS labeling and pictogram requirements are very relevant and must be understood by laboratory employees. Figure 2 illustrates the GHS label format showing the required elements.

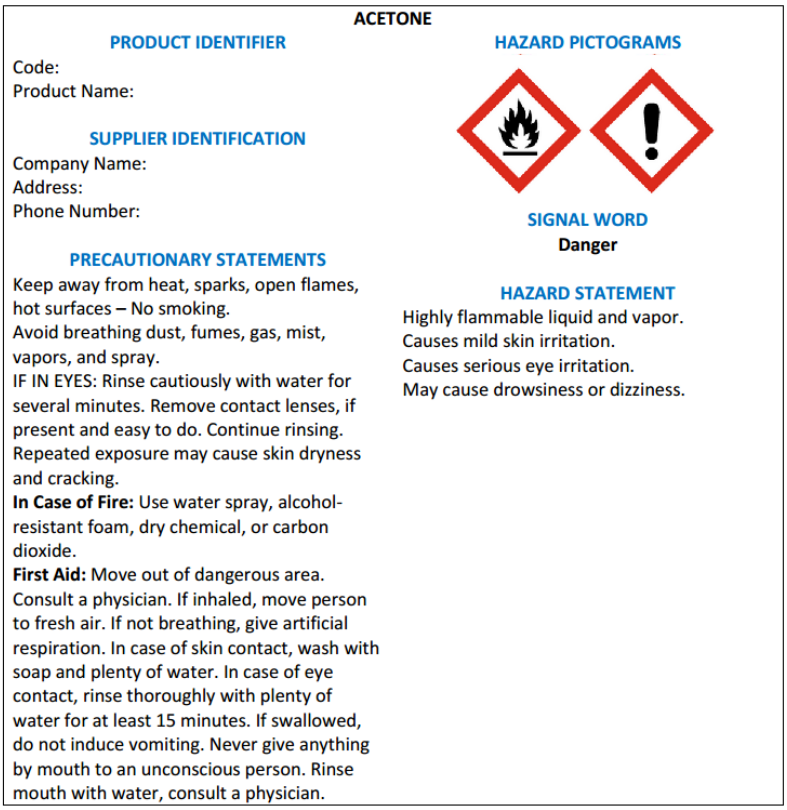


Figure 2 – GHS Label Format

As mentioned earlier, one of the objectives of GHS was to create a quantitative hazard classification system (numerical hazard classification is based on a 1 – 5 scale, 1 being the most hazardous and 5 being the least hazardous) based on physical characteristics such as flash point, boiling point, lethal dose of 50% of a population, reactivity, etc. Table 2 illustrates how the numerical hazard classification works for flammable liquids. More detailed information on GHS can be found on the OSHA website. (https://www.osha.gov/dsg/hazcom/global.html)

Table 2 – GHS Hazard Classification System for Flammable Liquids

Category	Criteria	Pictogram	Signal Word	Hazard Statement
1	Flash point < 23 °C Boiling point ≤ 35 °C		Danger	Extremely flammable liquid and vapor
2	Flash point < 23 °C Boiling point > 35 °C		Danger	Highly flammable liquid and vapor
3	Flash point ≥ 23 °C and < 60 °C		Warning	Flammable liquid and vapor
4	Flash point ≥ 60 °C and ≤ 93 °C		Warning	Combustible liquid
5	There is no Category 5 for flammable liquids			

2. National Fire Protection Association Rating System

The NFPA system uses a diamond-shaped diagram of symbols and numbers to indicate the degree of hazard associated with a particular chemical. This system was created to easily and quickly communicate hazards to first responders in the event of an emergency situation. These diamond-shaped symbols are placed on chemical containers to identify the degree of hazard associated with the specific chemical or chemical mixture. The NFPA system is a common way to identify chemical hazards and must be understood by laboratory employees. The NFPA 704 numerical rating system is based on a 0 – 4 system; 0 meaning no hazard and 4 meaning the most hazardous (note: this in contrast to the GHS system of 1 –5 where 1 is the most hazardous and 5 is the least hazardous). Figure 3 illustrates the NFPA hazard rating system and identifies both the hazard categories and hazard rating system. OSHA released the Comparison of NFPA 704 & HCS 2012 Labels QuickCard which can be found on the OSHA's website.

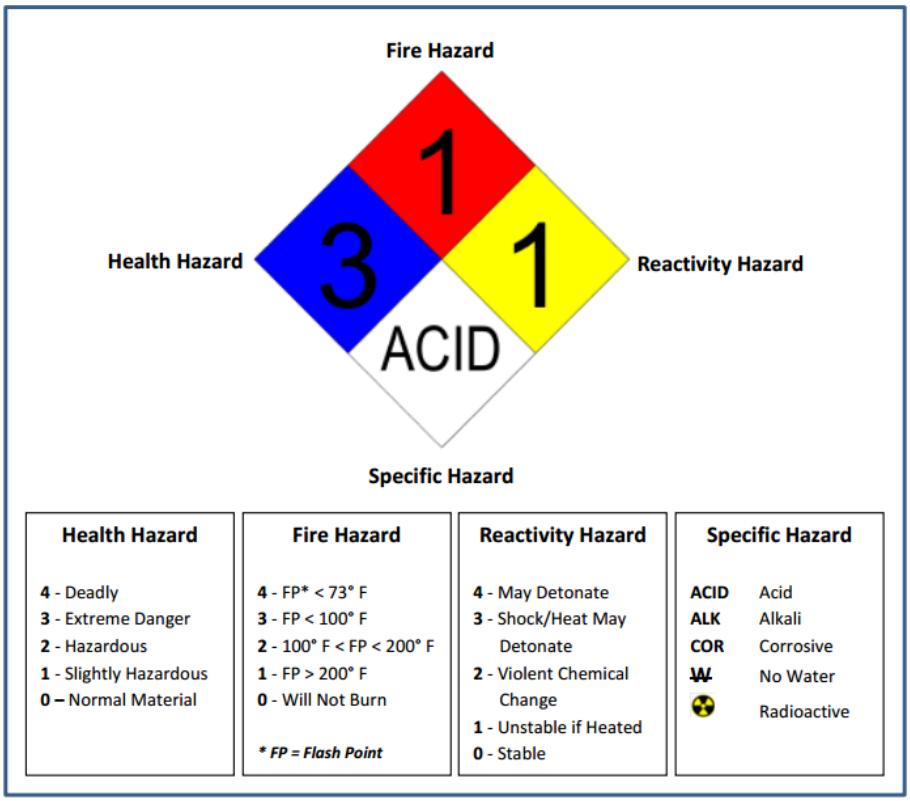


Figure 3 – NFPA Hazard Rating System

3. Department of Transportation Hazard Classes

The DOT regulates the transportation of all hazardous materials in the United States, and defines a hazardous material as any substance that has been determined to be capable of posing an unreasonable risk to health, safety, or property when transported in commerce. There are several methods that can be employed to determine whether a chemical is hazardous for transport, a few of which included:

- Reviewing the DOT Hazardous Materials Table (49 CFR 172.101);

- Reviewing the SDS, specifically Section 2: Hazardous Identification and Section 14: Transport Considerations, for the chemical being shipped, as detailed above in Section 1.1 of Appendix 2;

- Reviewing the chemical label and looking for hazard information detailed above in Section 1.2 of the Appendix 2; and

- Understanding the chemical and physical properties of the chemical.

All hazardous chemicals must be properly labeled by the chemical manufacturer or distributor before transportation occurs. Chemical containers stored in laboratories are not required to be labeled per DOT standards; however the nine DOT hazard classes are often seen on chemical containers and are discussed in Section 14 of GHS-formatted SDSs. The nine DOT hazard classes are illustrated below in Figure 4. Figure 4 only lists the primary hazard classes, the sub classes (e.g., Organic Peroxides, DOT Class 5.2) were omitted for stylistic purposes.

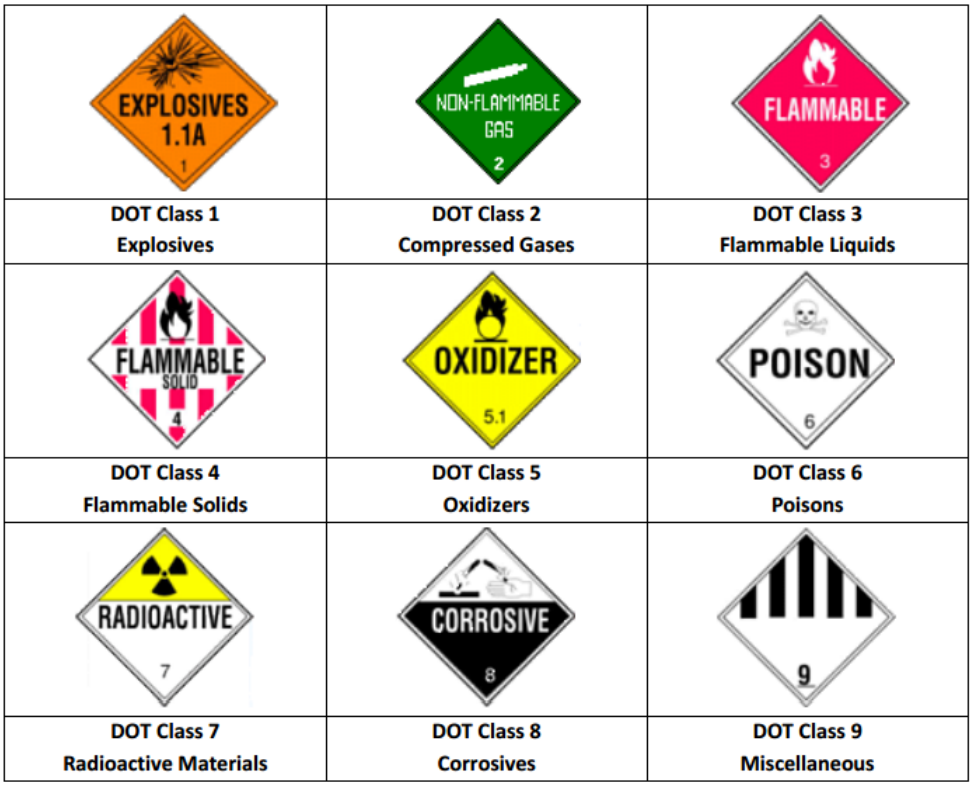


Figure 4 – DOT Hazard Classes

Appendix 3. Chemical Segregation & Incompatibilities Guidelines

Appendix 3. Chemical Segregation and Incompatibilities Guidelines

Class of Chemicals	Examples	Recommended Storage Method	Incompatible Materials – ALWAYS REFER TO SDS	Possible reactions if mixed
Corrosives Organic Acids and Acid Chlorides 	formic acid, acetic acid, propionic acid, butyric acid, acetic chloride dichlordimethylsilane Trifluoroacetic Acid, Trichloroacetic Acid	• Flammable acids should be stored in a flammable cabinet with a secondary containment. • Non flammable acids should store in a separate, lined/protected acid storage cabinet, or in deep corrosion-resistant spill trays. • Keep away from potential water sources (e.g. under sinks). DO NOT store acids directly on metal shelves. • ALWAYS STORE BELOW EYE LEVEL.	Flammable liquids, flammable solids, bases, oxidizers, and Inorganic acids Acid chlorides must be separated from amines.	HEAT, GAS GENERATION, VIOLENT REACTIONS
Corrosives Inorganic Acids 	Mineral Acids – Hydrochloric Acid, Hydrofluoric Acid, Phosphoric Acid, Sulfuric Acid, Chromic Acid, Perchloric Acid, Nitric Acid, Hydrobromic Acid	Store in a separate, lined/protected acid storage cabinet, or in deep corrosion-resistant spill trays. Keep away from potential water sources (e.g. under sinks). DO NOT store acids directly on metal shelves. ALWAYS STORE BELOW EYE LEVEL.	Flammable liquids, flammable solids, bases, organic acids, oxidizers, and poisons	HEAT, GAS GENERATION, VIOLENT REACTIONS
Corrosives Bases/Caustics 	Ammonium Hydroxide, Sodium Hydroxide (caustic soda), Potassium Hydroxide (caustic potash)	Store in a separate storage cabinet or segregate with a deep, corrosion-resistant spill tray. Keep away from potential water sources (e.g. under sinks). ALWAYS STORE BELOW EYE LEVEL	Flammable Liquids, Flammable Solids, Acids, Oxidizers, and poisons	HEAT, GAS GENERATION, VIOLENT REACTIONS
Explosives 	Ammonium Nitrate, Nitro Urea, Sodium amide, Trinitroaniline, Trinitroanisole, Trinitrobenzene, Trinitrophenol/Picric acid, Trinitrotoluene (TNT),	Store in a secure, cool, dry location away from all other chemicals. Do not store in an area where they can fall.	All other chemicals KEEP AWAY FROM HEAT AND IGNITION SOURCES SUCH AS DIRECT SUNLIGHT, HOT SURFACES, OPEN FLAMES, AND SPARK	EXPLOSION HAZARD

	Trinitrobenzoic Acid, azides, perchlorates.		SOURCES.	
Flammable Liquids 	Acetone, Benzene, Diethyl Ether, Methanol, Ethanol, Toluene, Hexanes	Store all except small working quantities in a flammables storage cabinet or an approved flammable storage refrigerator (if necessary).	Acids, Bases, Oxidizers, Poisons KEEP AWAY FROM HEAT AND IGNITION SOURCES SUCH AS HOT SURFACES, DIRECT SUNLIGHT, OPEN FLAMES, AND SPARK SOURCES.	FIRE HAZARD, HEAT, VIOLENT REACTIONS
Flammable Solids 	Phosphorus, Magnesium, Carbon	Store in a separated cool, dry area away from oxidizers and corrosives.	Acids, Bases, Oxidizers, Poisons KEEP AWAY FROM HEAT AND IGNITION SOURCES SUCH AS HOT SURFACES, DIRECT SUNLIGHT, OPEN FLAMES, AND SPARK SOURCES.	FIRE HAZARD, HEAT, VIOLENT REACTIONS
Peroxide Forming Chemicals	Diethyl Ether, Tetrahydrofuran, Dioxane	Store in an NFPA approved flammables storage cabinet. ALL PEROXIDE FORMING CHEMICALS MUST BE DATED UPON RECEIPT AND OPENING.	Acids, Bases, Oxidizers, Poisons KEEP AWAY FROM IGNITION SOURCES	EXPLOSION HAZARD
Oxidizers 	Sodium Hypochlorite, Benzoyl Peroxide, Potassium Permanganate, Potassium Dichromate, Peroxides, Perchlorates, Chlorates, Nitrates, Bromates, Superoxides	Store in a deep spill containment tray inside a non-combustible cabinet, separate from flammable or combustible materials and reducing agents. Store inorganic oxidizers and organic peroxides separate from each other via secondary containment (e.g. trays).	Reducing agents, flammables, combustibles, organic materials, corrosives; VERY STRONG OXIDIZERS SHOULD BE STORED IN GLASS OR INERT CONTAINERS. DO NOT USE CORKS OR RUBBER STOPPERS.	FIRE HAZARD, TOXIC GAS GENERATION
Water Reactive Materials	Sodium metal, Potassium metal, Lithium metal, Hydrides such as Lithium Aluminum hydride or Sodium Hydride,	Store in a cool, dry location away from potential water sources (e.g. sprinkler systems, under sinks). Examples of suitable locations include dessicators	Aqueous Solutions, Oxidizers	HEAT, VIOLENT REACTIONS

	Borohydrides	or glove boxes filled with dry gases. LABEL LOCATION OF STORAGE AREAS AS "WATER REACTIVE CHEMICALS." MANY WATER REACTIVE CHEMICALS ARE FLAMMABLE SOLIDS. IF FLAMMABLE SOLID, STORE AS SUCH. IF NOT, STORE SEPARATELY FROM ALL OTHER CHEMICALS.		
Reducing Agents	Lithium Aluminum Hydride, Sodium Amalgam, Sodium Borohydride, Diisobutyl Aluminum Hydride, Formic Acid, Oxalic Acid	Store in a deep spill containment tray inside a non-combustible cabinet separate from oxidizers.	Oxidizers, Arsenic, Selenides	FIRE HAZARD, TOXIC GAS GENERATION
Flammable Compressed Gases 	Methane, Acetylene, Propane	Store in a cool, dry area away from oxidizing gases. Securely strap or chain cylinders. DO NOT STORE LECTURE SIZED GAS CYLINDERS IN CABINETS WITH HAZARDOUS LIQUIDS.	Oxidizing and Toxic Compressed Gases, Oxidizing Solids	FIRE HAZARD AND EXPLOSION HAZARD
Oxidizing Compressed Gases 	Oxygen, Chlorine, Bromine	Store in a cool, dry area away from flammable gases and liquids. Securely strap or chain cylinders. DO NOT STORE LECTURE SIZED GAS CYLINDERS IN CABINETS WITH HAZARDOUS LIQUIDS	Flammable Gases	FIRE HAZARD AND EXPLOSION HAZARD

Poisonous Compressed Gases 	Carbon Monoxide, Hydrogen Sulfide	Cylinders containing the compressed gases listed in this section must be kept in a continuously, mechanically ventilated enclosure.	Flammable and/or oxidizing gases	RELEASE OF TOXIC GAS, VIOLENT REACTIONS
Inert Compressed Gases 	Nitrogen, Helium, Argon	Store in a cool, dry area. Securely strap or chain cylinders. DO NOT STORE LECTURE SIZED GAS CYLINDERS IN CABINETS WITH HAZARDOUS LIQUIDS	Refer to SDS	REFER TO SDS

Appendix 4. PHS List

This list of Particularly Hazardous Substances (PHS's) is provided to help you comply with the OSHA Hazardous Chemicals in Laboratory Standard (Code of Federal Regulations, Title 29, Part 1910.1450). These chemicals may present extreme risk potential to laboratory personnel if not handled appropriately; therefore, these substances may require additional control measures when used.

It is important to note that the list must not be considered "all inclusive"! Many other chemicals that are not listed may also possess extremely hazardous properties. Principle Investigators are responsible for assessing the hazards of chemical materials that their Laboratory Personnel may use or synthesize, and to take appropriate steps to implement safety controls.

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen: Known	Human Carcinogen: Probable	Reproductive Hazard: Female	Reproductive Hazard: Male	Reproductive Hazard: Fetal	Reactive
	Nickel compounds	☐	☑	☐	☐	☐	☐	☐
	Chromium [VI] Compunds	☐	☑	☐	☐	☐	☐	☐
	Cadmium compounds	☐	☑	☐	☐	☐	☐	☐
	Chlorophenols (polychlorophenols)	☐	☐	☑	☐	☐	☐	☐
	Hexachlorocyclohexanes	☐	☐	☑	☐	☐	☐	☐
	Lead compounds, inorganic	☐	☐	☑	☑	☑	☑	☐
	Methyl and other organic mercury compounds	☑	☐	☑	☐	☐	☑	☐
	Polychlorinated biphenyls (PCBs) - all forms	☐	☐	☑	☑	☑	☑	☐
	Organolithium compounds	☐	☐	☐	☐	☐	☐	☑
	Botulinum Toxins	☑	☐	☐	☐	☐	☐	☐
	Clostridium perfringens, epsilon toxin	☑	☐	☐	☐	☐	☐	☐
	Conotoxins	☑	☐	☐	☐	☐	☐	☐
	Ricin isolates	☑	☐	☐	☐	☐	☐	☐
	Saxitoxins	☑	☐	☐	☐	☐	☐	☐
	Staphylococcal enterotoxins	☑	☐	☐	☐	☐	☐	☐
	Tetrodotoxins	☑	☐	☐	☐	☐	☐	☐
	Tricothecene mycotoxins	☑	☐	☐	☐	☐	☐	☐
50–00–0	Formaldehyde (Formalin) (Paraformaldeyde)	☑	☑	☐	☐	☐	☐	☐
50–06–6	Phenobarbital	☐	☐	☑	☐	☐	☐	☐
50–07–7	Mitomycin C	☐	☐	☑	☐	☐	☐	☐
50–18–0	Cyclophosphamide	☐	☑	☐	☐	☐	☑	☐
50–29–3	DDT [p,p'-DDT]	☐	☐	☑	☐	☐	☐	☐
50–32–8	Benzo[a]pyrene	☐	☑	☐	☐	☐	☐	☐
50–35–1	Thalidomide	☐	☐	☐	☐	☐	☑	☐
50–55–5	Reserpine	☐	☐	☑	☐	☐	☐	☐
51–21–8	5-Fluorouracil	☐	☐	☐	☐	☐	☑	☐
51–28–5	Dinitrophenol	☐	☐	☐	☐	☐	☐	☑

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
51–52–5	Propylthiouracil	☐	☐	☑	☐	☐	☑	☐
51–75–2	HN2 (nitrogen mustard-2)	☐	☐	☑	☐	☐	☑	☐
51–79–6	Ethyl carbamate (Urethane)	☐	☐	☑	☐	☐	☐	☐
52–24–4	Thiotepa	☐	☑	☐	☐	☐	☐	☐
52–67–5	Valine, 3-mercapto-, D-	☐	☐	☐	☐	☐	☑	☐
53–70–3	Dibenz [a,h]anthracene	☐	☐	☑	☐	☐	☐	☐
53–96–3	2-acetylaminofluorene	☐	☑	☐	☐	☐	☐	☐
54–62–6	Aminopterin	☐	☐	☐	☐	☐	☑	☐
55–18–5	N-Nitrosodiethylamine	☐	☐	☑	☐	☐	☐	☐
55–63–0	Nitrogycerine	☐	☐	☐	☐	☐	☐	☑
55–86–7	Nitrogen Mustard Hydrochloride	☐	☐	☑	☐	☐	☐	☐
55–98–1	1,4-Butanediol dimethanesulfonate (Busulfan; Myleran)	☐	☑	☐	☑	☑	☑	☐
56–04–2	Methylthiouracil	☐	☐	☑	☐	☐	☐	☐
56–23–5	Carbon tetrachloride	☐	☐	☑	☐	☐	☐	☐
56–53–1	Diethylstilboestrol	☐	☑	☐	☐	☐	☑	☐
56–55–3	Benz[a]anthracene	☐	☐	☑	☐	☐	☐	☐
56–75–7	Chloramphenicol	☐	☐	☑	☐	☐	☐	☐
57–14–7	1,1-Dimethylhydrazine	☑	☐	☑	☐	☐	☐	☐
57–41–0	Phenytoin	☐	☐	☑	☐	☐	☑	☐
57–57–8	beta-propiolactone	☐	☑	☐	☐	☐	☐	☐
57–74–9	Chlordane	☐	☐	☑	☐	☐	☐	☐
57–83–0	Progesterone	☐	☐	☑	☐	☐	☐	☐
58–18–4	Methyltestosterone	☐	☐	☐	☐	☐	☑	☐
58–89–9	Lindane	☐	☐	☑	☐	☐	☐	☐
59–05–2	Methotrexate	☐	☐	☐	☑	☐	☑	☐
59–89–2	N-Nitrosomorpholine	☐	☐	☑	☐	☐	☐	☐
60–09–3	para-Aminoazobenzene	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
60–11–7	4-Dimethylaminoazo-benzene	☐	☑	☐	☐	☐	☐	☐
60–29–7	Diethyl ether	☐	☐	☐	☐	☐	☐	☑
60–34–4	Methyl hydrazine	☑	☐	☐	☐	☐	☐	☐
60–35–5	Acetamide	☐	☐	☑	☐	☐	☐	☐
60–56–0	Methiamazole	☐	☐	☐	☐	☐	☑	☐
61–57–4	Niridazole	☐	☐	☑	☐	☐	☐	☐
61–82–5	Amitrole	☐	☐	☑	☐	☐	☐	☐
62–44–2	Phenacetin	☐	☐	☑	☐	☐	☐	☐
62–50–0	Ethyl methanesulfonate	☐	☐	☑	☐	☐	☐	☐
62–53–3	Aniline	☐	☐	☐	☐	☐	☑	☐
62–55–5	Thioacetamide	☐	☐	☑	☐	☐	☐	☐
62–56–6	Thiourea	☐	☐	☑	☐	☐	☐	☐
62–73–7	Dichlorvos	☐	☐	☑	☐	☐	☐	☐
62–75–9	N-nitrosodimethylamine	☐	☑	☐	☐	☐	☐	☐
63–92–3	Phenoxybenzamine hydrochloride	☐	☐	☑	☐	☐	☐	☐
64–67–5	Diethyl sulfate	☐	☐	☑	☐	☐	☐	☐
66–27–3	Methyl methanesulfonate	☐	☐	☑	☐	☐	☐	☐
66–75–1	Uracil mustard	☐	☐	☑	☐	☐	☐	☐
66–76–2	Dicumarol	☐	☐	☐	☐	☐	☑	☐
67–20–9	Nitrofurantoin	☐	☐	☐	☐	☑	☐	☐
67–66–3	Chloroform [Methane, trichloro-]	☐	☐	☑	☐	☐	☐	☐
67–72–1	Hexachloroethane	☐	☐	☑	☐	☐	☐	☐
68–22–4	Norethisterone	☐	☐	☑	☐	☐	☐	☐
70–25–7	N-Methyl-N´-nitro-N-nitrosoguanidine (MNNG)	☐	☐	☑	☐	☐	☐	☑
71–43–2	Benzene	☐	☑	☐	☐	☐	☐	☐
71–58–9	Medroxyprogesterone acetate	☐	☐	☑	☐	☐	☐	☐
72–57–1	Trypan blue	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
74–83–9	Methyl bromide	☑	☐	☐	☐	☐	☐	☐
74–86–2	Acetylene	☐	☐	☐	☐	☐	☐	☑
74–89–5	Methylamine	☑	☐	☐	☐	☐	☐	☐
74–90–8	Hydrogen cyanide (gas)	☑	☐	☐	☐	☐	☐	☐
74–93–1	Methyl mercaptan	☑	☐	☐	☐	☐	☐	☐
75–01–4	Vinyl chloride	☐	☑	☐	☐	☐	☐	☐
75–02–5	Vinyl fluoride	☐	☐	☑	☐	☐	☐	☐
75–07–0	Acetaldehyde	☑	☐	☑	☐	☐	☐	☐
75–09–2	Methylene Chloride (dichloromethane)	☐	☑	☐	☐	☐	☑	☐
75–15–0	Carbon disulfide	☑	☐	☐	☑	☑	☑	☐
75–20–7	Calcium carbide	☐	☐	☐	☐	☐	☐	☑
75–21–8	Ethylene Oxide	☑	☑	☐	☑	☐	☐	☑
75–27–4	Bromodichloromethane	☐	☐	☑	☐	☐	☐	☐
75–35–4	Vinylidene chloride	☐	☐	☐	☐	☐	☐	☑
75–44–5	Phosgene	☑	☐	☐	☐	☐	☐	☐
75–52–5	Nitromethane	☐	☐	☑	☐	☐	☐	☑
75–55–8	Propyleneimine (Aziridine, 2- methyl-)	☐	☐	☑	☐	☐	☐	☐
75–56–9	Propylene Oxide	☑	☐	☑	☐	☐	☐	☐
75–74–1	Tetramethyl lead	☑	☐	☐	☐	☐	☐	☐
75–77–4	Trimethylchlorosilane	☑	☐	☐	☐	☐	☐	☐
75–78–5	Dimethyldichlorosilane	☑	☐	☐	☐	☐	☐	☐
75–79–6	Methyltrichlorosilane	☑	☐	☐	☐	☐	☐	☐
75–86–5	Acetone cyanohydrin	☑	☐	☐	☐	☐	☐	☐
75–91–2	t-Butyl hydroperoxide	☐	☐	☐	☐	☐	☐	☑
76–06–2	Chloropicrin	☑	☐	☐	☐	☐	☐	☐
76–44–8	Heptachlor	☐	☐	☑	☐	☐	☐	☐
77–09–8	Phenolphthalein	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
77–47–4	Hexachlorocyclopentadiene	☑	☐	☐	☐	☐	☐	☐
77–73–6	Dicyclopentadiene	☐	☐	☐	☐	☐	☐	☑
77–78–1	Dimethyl Sulfate	☑	☐	☑	☐	☐	☐	☐
78–11–5	Erythritol tetranitrate (PETN)	☐	☐	☐	☐	☐	☐	☑
78–53–5	o,o-Diethyl S-[2-(diethylamino)ethyl] phosphorothiolate	☐	☑	☐	☐	☐	☐	☐
78–79–5	Isoprene	☐	☐	☑	☐	☐	☐	☐
78–82–0	Isobutyronitrile	☑	☐	☐	☐	☐	☐	☐
78–85–3	Methacrylaldehyde	☑	☐	☐	☐	☐	☐	☐
78–94–4	Methyl vinyl ketone	☑	☐	☐	☐	☐	☐	☑
78–95–5	Chloroacetone, stabilized	☑	☐	☐	☐	☐	☐	☐
79–01–6	Trichloroethylene	☐	☐	☑	☐	☐	☐	☐
79–04–9	Chloroacetyl Chloride	☑	☐	☐	☐	☐	☐	☐
79–06–1	Acrylamide	☐	☐	☑	☐	☐	☐	☐
79–10–7	Acrylic acid	☑	☐	☐	☐	☐	☐	☐
79–21–0	Peracetic Acid	☑	☐	☐	☐	☐	☐	☑
79–22–1	Methyl chloroformate	☑	☐	☐	☐	☐	☐	☐
79–43–6	Dichloroacetic acid	☐	☐	☑	☐	☐	☐	☐
79–44–7	Dimethylcarbamoyl chloride	☐	☐	☑	☐	☐	☐	☐
79–46–9	2-Nitropropane	☐	☐	☑	☐	☐	☐	☐
80–15–9	Cumene Hydroperoxide	☑	☐	☐	☐	☐	☐	☑
80–43–3	Cumene peroxide	☐	☐	☐	☐	☐	☐	☑
81–49–2	1-Amino-2,4-dibromoanthraquinone	☐	☐	☑	☐	☐	☐	☐
81–81–2	Coumarin, 3-(alpha-acetonylbenzyl)-4-hydroxy-	☐	☐	☐	☐	☐	☑	☐
82–28–0	1-Amino-2-methylanthraquinone	☐	☐	☑	☐	☐	☐	☐
82–71–3	Trinitroresorcinol	☐	☐	☐	☐	☐	☐	☑
87–31–0	Diazodinitrophenol	☐	☐	☐	☐	☐	☐	☑
87–62–7	2,6-Dimethylaniline (2,6-Xylidine)	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
87–68–3	Hexachlorobutadiene	☑	☐	☐	☐	☐	☐	☐
88–06–2	2,4,6-Trichlorophenol	☐	☐	☑	☐	☐	☐	☐
88–88–0	Picryl chloride	☐	☐	☐	☐	☐	☐	☑
88–89–1	Picric acid (trinitrophenol)	☐	☐	☐	☐	☐	☐	☑
90–04–0	ortho-Anisidine	☐	☐	☑	☐	☐	☐	☐
90–94–8	Michler's ketone (4,4'-bis(dimethylamino)benzophenone)	☐	☐	☑	☐	☐	☐	☐
91–17–8	Decahydronaphthalene	☐	☐	☐	☐	☐	☐	☑
91–20–3	Naphthalene	☐	☐	☑	☐	☐	☐	☐
91–23–6	2-Nitroanisole	☐	☐	☑	☐	☐	☐	☐
91–59–8	2-Naphthylamine	☐	☑	☐	☐	☐	☐	☐
91–94–1	3,3'-Dichlorobenzidine and salts	☐	☑	☐	☐	☐	☐	☐
92–67–1	4-Aminobiphenyl	☐	☑	☐	☐	☐	☐	☐
92–87–5	Benzidine	☐	☑	☐	☐	☐	☐	☐
93–15–2	Methyleugenol	☐	☐	☑	☐	☐	☐	☐
94–36–0	Benzoyl peroxide	☐	☐	☐	☐	☐	☐	☑
94–58–6	Dihydrosafrole	☐	☐	☑	☐	☐	☐	☐
94–59–7	Safrole	☐	☐	☑	☐	☐	☐	☐
95–06–7	Sulfallate	☐	☐	☑	☐	☐	☐	☐
95–53–4	ortho-Toluidine	☐	☑	☐	☐	☐	☐	☐
95–69–2	4-Chloro-ortho-toluidine	☐	☐	☑	☐	☐	☐	☐
95–80–7	2,4-Diaminotoluene	☐	☐	☑	☐	☐	☐	☐
95–83–0	4-Chloro-ortho-phenylenediamine	☐	☐	☑	☐	☐	☐	☐
96–09–3	Styrene-7,8-oxide	☐	☐	☑	☐	☐	☐	☐
96–12–8	1,2-Dibromo-3-chloropropane	☐	☑	☐	☐	☑	☐	☐
96–13–9	2,3-Dibromo-1-propanol	☐	☐	☑	☐	☐	☐	☐
96–18–4	1,2,3-Trichloropropane	☐	☐	☑	☐	☐	☐	☐
96–45–7	Ethylene Thiourea	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
96–91–3	Picramic acid	☐	☐	☐	☐	☐	☐	☑
97–56–3	ortho-Aminoazotoluene	☐	☐	☑	☐	☐	☐	☐
98–07–7	benzotrichloride	☐	☐	☑	☐	☐	☐	☐
98–87–3	benzal chloride	☐	☐	☑	☐	☐	☐	☐
98–88–4	Benzoyl chloride	☑	☐	☑	☐	☐	☐	☐
98–95–3	Nitrobenzene	☐	☐	☑	☐	☑	☐	☐
99–35–4	Trinitrobenzene	☐	☐	☐	☐	☐	☐	☑
99–66–1	Valproate (Valproic acid)	☐	☐	☐	☐	☐	☑	☐
100–40–3	4-Vinylcyclohexene	☐	☐	☑	☐	☐	☐	☐
100–41–4	Ethylbenzene	☐	☐	☑	☐	☐	☐	☐
100–42–5	Styrene	☐	☐	☑	☐	☐	☐	☑
100–44–7	Benzyl Chloride	☑	☐	☑	☐	☐	☐	☐
100–66–3	Anisole	☐	☐	☐	☐	☐	☐	☑
100–75–4	N-Nitrosopiperidine	☐	☐	☑	☐	☐	☐	☐
101–14–4	4,4´-Methylenebis(2-chloroaniline)	☐	☑	☐	☐	☐	☐	☐
101–61–1	Michler's base (4,4'-methylenebis(N,N-dimethyl)benzenamine)	☐	☐	☑	☐	☐	☐	☐
101–68–8	4,4'-Methylenediphenyl diisocyanate	☑	☐	☐	☐	☐	☐	☐
101–77–9	Methylenedianiline	☐	☑	☐	☐	☐	☐	☐
101–80–4	4,4'-Oxydianiline	☐	☐	☑	☐	☐	☐	☐
101–90–6	Diglycidyl resorcinol ether	☐	☐	☑	☐	☐	☐	☐
103–50–4	Dibenzyl ether	☐	☐	☐	☐	☐	☐	☑
103–71–9	Phenyl isocyanate	☑	☐	☐	☐	☐	☐	☐
105–57–7	Acetal	☐	☐	☐	☐	☐	☐	☑
105–74–8	Dodecanoyl peroxide	☐	☐	☐	☐	☐	☐	☑
106–46–7	para-Dichlorobenzene	☐	☐	☑	☐	☐	☐	☐
106–47–8	para-Chloroaniline	☐	☐	☑	☐	☐	☐	☐
106–87–6	4-Vinylcyclohexene diepoxide	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
106–88–7	1,2-Epoxybutane	☐	☐	☑	☐	☐	☐	☐
106–89–8	Epichlorohydrin	☑	☐	☑	☐	☐	☐	☐
106–93–4	1,2-Dibromoethane (Ethylene Dibromide)	☐	☐	☑	☐	☐	☐	☐
106–96–7	Bromopropyne (Propargyl bromide)	☐	☐	☐	☐	☐	☐	☑
106–99–0	1,3-Butadiene	☐	☑	☐	☐	☐	☐	☐
107–02–8	Acrolein (2-Propenal)	☑	☐	☐	☐	☐	☐	☐
107–06–2	1,2-Dichloroethane	☐	☐	☑	☐	☐	☐	☐
107–07–3	2-Chloroethanol	☑	☐	☐	☐	☐	☐	☐
107–13–1	Acrylonitrile (2-Propenenitrile)	☑	☑	☐	☐	☐	☐	☐
107–18–6	Allyl alcohol (2-Propen-l-ol)	☑	☐	☐	☐	☐	☐	☐
107–20–0	2-Chloroethanal	☑	☐	☐	☐	☐	☐	☐
107–30–2	Chloromethyl methyl ether	☑	☑	☐	☐	☐	☐	☐
107–44–8	Sarin	☑	☐	☐	☐	☐	☐	☐
108–05–4	Vinyl acetate monomer (Acetic acid ethenyl ester)	☐	☐	☑	☐	☐	☐	☑
108–10–1	Methyl iso-butyl ketone	☐	☐	☐	☐	☐	☐	☑
108–20–3	isopropyl ether	☐	☐	☐	☐	☐	☐	☑
108–23–6	Isopropylchloroformate	☑	☐	☐	☐	☐	☐	☐
108–88–3	Toluene	☐	☐	☐	☑	☐	☑	☐
108–95–2	Phenol	☑	☐	☐	☐	☐	☑	☐
109–53–5	vinyl iso butyl ether	☐	☐	☐	☐	☐	☐	☑
109–86–4	Ethylene glycol monomethyl ether	☐	☐	☐	☐	☐	☐	☑
109–92–2	Ethyl vinyl ether	☐	☐	☐	☐	☐	☐	☑
109–99–9	Tetrahydrofuran	☐	☐	☐	☐	☐	☐	☑
110–00–9	Furan	☐	☐	☑	☐	☐	☐	☑
110–22–5	Acetyl peroxide	☐	☐	☐	☐	☐	☐	☑
110–78–1	n-Propyl isocyanate	☑	☐	☐	☐	☐	☐	☐
111–36–4	n-Butyl isocyanate	☑	☐	☐	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
111–96–6	Diethylene glycol diemethyl ether	☐	☐	☐	☐	☐	☐	☑
115–02–6	Azaserine	☐	☐	☑	☐	☐	☐	☐
115–28–6	Chlorendic acid	☐	☐	☑	☐	☐	☐	☐
115–67–3	Paramethadione	☐	☐	☐	☐	☐	☑	☐
116–14–3	Tetrafluoroethylene	☐	☐	☑	☐	☐	☐	☐
117–10–2	Dantron (Chrysazin; 1,8-Dihydroxyanthraquinone)	☐	☐	☑	☐	☐	☐	☐
117–79–3	2-Aminoanthraquinone	☐	☐	☑	☐	☐	☐	☐
117–81–7	di(2-Ethylhexyl) Phthalate	☐	☐	☑	☐	☐	☐	☐
118–74–1	Hexachlorobenzene	☐	☐	☑	☐	☐	☐	☐
118–96–7	Trinitrotoluene (TNT)	☐	☐	☐	☐	☐	☐	☑
119–64–2	Tetralin	☐	☐	☐	☐	☐	☐	☑
119–90–4	3,3'-Dimethoxybenzidine (ortho-Dianisidine)	☐	☐	☑	☐	☐	☐	☐
119–93–7	3,3'-Dimethylbenzidine (ortho-Tolidine)	☐	☐	☑	☐	☐	☐	☐
120–71–8	para-Cresidine	☐	☐	☑	☐	☐	☐	☐
120–80–9	Catechol	☐	☐	☑	☐	☐	☐	☐
121–14–2	2,4-Dinitrotoluene	☐	☐	☑	☐	☐	☑	☐
121–82–4	Cyclotrimethylenetrinitramine (RDX) (Hexolite)	☐	☐	☐	☐	☐	☐	☑
122–60–1	Phenyl glycidyl ether (PGE)	☐	☐	☑	☐	☑	☐	☐
122–66–7	Hydrazobenzene	☐	☐	☑	☐	☐	☐	☐
123–91–1	1,4-Dioxane	☐	☐	☑	☐	☐	☐	☑
124–43–6	Urea Peroxide	☐	☐	☐	☐	☐	☐	☑
124–47–0	Urea nitrate	☐	☐	☐	☐	☐	☐	☑
126–07–8	Griseofulvin	☐	☐	☑	☐	☐	☐	☐
126–72–7	Tris(2,3-dibromopropyl) phosphate	☐	☐	☑	☐	☐	☐	☐
126–85–2	Nitrogen mustard N-oxide	☐	☐	☑	☐	☐	☐	☐
126–98–7	Methacrylonitrile (2- Propenenitrile, 2-methyl-)	☑	☐	☐	☐	☐	☐	☐
126–99–8	Chloroprene	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
127–07–1	Hydroxyurea	☐	☐	☐	☐	☐	☑	☐
127–18–4	Tetrachloroethylene	☐	☐	☑	☐	☐	☐	☐
127–48–0	Trimethadione	☐	☐	☐	☐	☐	☑	☐
129–15–7	2-Methyl-1-nitroanthraquinone	☐	☐	☑	☐	☐	☐	☐
129–43–1	1-Hydroxyanthraquinone	☐	☐	☑	☐	☐	☐	☐
129–66–8	Trinitrobenzoic acid	☐	☐	☐	☐	☐	☐	☑
131–73–7	Dipicrylamine	☐	☐	☐	☐	☐	☐	☑
131–74–8	Ammonium picrate	☐	☐	☐	☐	☐	☐	☑
132–27–4	Sodium ortho-phenylphenate	☐	☐	☑	☐	☐	☐	☐
134–29–2	o-Anisidine Hydrochloride	☐	☐	☑	☐	☐	☐	☐
134–32–7	alpha-Napthylamine	☐	☑	☐	☐	☐	☐	☐
135–20–6	Cupferron	☐	☐	☑	☐	☐	☐	☐
136–35–6	Diazoaminobenzene	☐	☐	☑	☐	☐	☐	☐
136–40–3	Phenazopyridine hydrochloride	☐	☐	☑	☐	☐	☐	☐
139–13–9	Nitrilotriacetic acid	☐	☐	☑	☐	☐	☐	☐
139–65–1	4,4'-Thiodianiline	☐	☐	☑	☐	☐	☐	☐
140–57–8	Aramite®	☐	☐	☑	☐	☐	☐	☐
140–88–5	Ethyl acrylate	☐	☐	☑	☐	☐	☐	☐
141–90–2	Thiouracil	☐	☐	☑	☐	☐	☐	☐
142–96–1	n-Butyl Ether	☐	☐	☐	☐	☐	☐	☑
143–50–0	Chlordecone (Kepone)	☐	☐	☑	☐	☐	☐	☐
147–94–4	Cytarabine	☐	☐	☐	☐	☐	☑	☐
148–82–3	Melphalan	☐	☑	☐	☐	☐	☐	☐
151–56–4	Ethyleneimine (Aziridine)	☐	☑	☐	☐	☐	☐	☐
154–42–7	Thioguanine	☐	☐	☐	☐	☐	☑	☐
154–93–8	Bischloroethyl nitrosourea (BCNU)	☐	☐	☑	☐	☐	☐	☐
189–55–9	Dibenzo[a,i]pyrene	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen: Known	Human Carcinogen: Probable	Reproductive Hazard: Female	Reproductive Hazard: Male	Reproductive Hazard: Fetal	Reactive
189–64–0	Dibenzo[a,h]pyrene	☐	☐	☑	☐	☐	☐	☐
191–30–0	Dibenzo[a,l]pyrene	☐	☐	☑	☐	☐	☐	☐
192–65–4	Dibenzo[a,e]pyrene	☐	☐	☑	☐	☐	☐	☐
193–39–5	Indeno[1,2,3-cd]pyrene	☐	☐	☑	☐	☐	☐	☐
194–59–2	7H-Dibenzo[c,g]carbazole	☐	☐	☑	☐	☐	☐	☐
195–19–7	Benzo[c]phenanthrene	☐	☐	☑	☐	☐	☐	☐
202–33–5	Benz[j]aceanthrylene	☐	☐	☑	☐	☐	☐	☐
205–82–3	Benzo[j]fluoranthene	☐	☐	☑	☐	☐	☐	☐
205–99–2	Benzo[b]fluoranthene	☐	☐	☑	☐	☐	☐	☐
207–08–9	Benzo[k]fluoranthene	☐	☐	☑	☐	☐	☐	☐
218–01–9	Chrysene	☐	☐	☑	☐	☐	☐	☐
224–42–0	Dibenz[a,j]acridine	☐	☐	☑	☐	☐	☐	☐
226–36–8	Dibenz[a,h]acridine	☐	☐	☑	☐	☐	☐	☐
271–89–6	Benzofuran	☐	☐	☑	☐	☐	☐	☐
298–81–7	8-Methoxypsoralen (Methoxsalen) plus ultraviolet A radiation	☐	☑	☐	☐	☐	☐	☐
299–75–2	Treosulfan	☐	☑	☐	☐	☐	☐	☐
302–01–2	Hydrazine	☑	☐	☑	☐	☐	☐	☐
303–34–4	Lasiocarpine	☐	☐	☑	☐	☐	☐	☐
303–47–9	Ochratoxin A	☐	☐	☑	☐	☐	☐	☐
305–03–3	Chlorambucil	☐	☑	☐	☑	☑	☑	☐
315–22–0	Monocrotaline	☐	☐	☑	☐	☐	☐	☐
320–67–2	Azacitidine	☐	☐	☑	☐	☐	☐	☐
331–39–5	Caffeic acid	☐	☐	☑	☐	☐	☐	☐
353–42–4	Boron trifluoride	☐	☐	☐	☐	☐	☐	☑
366–70–1	Procarbazine hydrochloride	☐	☐	☑	☐	☐	☑	☐
434–07–1	Oxymetholone	☐	☐	☑	☐	☐	☐	☐
435–97–2	Phenprocoumon	☐	☐	☐	☐	☐	☑	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
443–48–1	Metronidazole	☐	☐	☑	☐	☐	☐	☐
446–86–6	Azathioprine	☐	☑	☐	☐	☐	☐	☐
460–19–5	Cyanogen	☑	☐	☐	☐	☐	☐	☐
463–51–4	Ketene	☑	☐	☐	☐	☐	☐	☐
463–58–1	Carbonyl sulfide	☑	☐	☐	☐	☐	☐	☐
463–71–8	Thiophosgene	☑	☐	☐	☐	☐	☐	☐
484–20–8	5-Methoxypsoralen	☐	☐	☑	☐	☐	☐	☐
489–98–5	Picramide (2,4,6-trinitrotoluene)	☐	☐	☐	☐	☐	☐	☑
492–80–8	Auramine	☐	☐	☑	☐	☐	☐	☐
494–03–1	N, N-Bis(2-chloroethyl)-2-naphthylamine (Chlornaphazine)	☐	☑	☐	☐	☐	☐	☐
505–60–2	Mustard gas (Sulfur mustard)	☐	☑	☐	☐	☐	☐	☐
506–68–3	Cyanogen bromide	☑	☐	☐	☐	☐	☐	☐
506–77–4	Cyanogen chloride	☑	☐	☐	☐	☐	☐	☐
507–40–4	tert-Butyl hypochlorite	☐	☐	☐	☐	☐	☐	☑
509–14–8	Tetranitromethane (Methane, tetranitro-)	☐	☐	☑	☐	☐	☐	☑
513–37–1	1-Chloro-2-methylpropene (Dimethylvinyl Chloride)	☐	☐	☑	☐	☐	☐	☐
531–76–0	Merphalan	☐	☐	☑	☐	☐	☐	☐
531–82–8	N-[4-(5-Nitro-2-furyl)-2-thiazolyl]acetamide	☐	☐	☑	☐	☐	☐	☐
540–73–8	Dimethylhydrazine, symmetrical	☑	☐	☑	☐	☐	☐	☐
541–41–3	Ethyl chloroformate	☑	☐	☐	☐	☐	☐	☐
542–75–6	1,3-Dichloropropene	☐	☐	☑	☐	☐	☐	☐
542–88–1	Chloromethyl ether (Methane, oxybis[chloro-])	☐	☑	☐	☐	☐	☐	☐
542–92–7	cyclopentadiene	☐	☐	☐	☐	☐	☐	☑
543–27–1	Isobutyl chloroformate	☑	☐	☐	☐	☐	☐	☐
544–97–8	Dimethylzinc	☐	☐	☐	☐	☐	☐	☑
555–54–4	Magnesium diphenyl	☐	☐	☐	☐	☐	☐	☑
555–84–0	1-[(5-Nitrofurfurylidene)amino]-2-imidazolidinone	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
556–52–5	Glycidol	☐	☐	☑	☐	☐	☐	☐
556–88–7	Nitroguanidine (Picrite)	☐	☐	☐	☐	☐	☐	☑
556–89–8	Nitrourea	☐	☐	☐	☐	☐	☐	☑
557–20–0	Diethylzinc	☐	☐	☐	☐	☐	☐	☑
563–47–3	3-Chloro-2-methylpropene	☐	☐	☑	☐	☐	☐	☐
569–61–9	CI Basic Red 9	☐	☐	☑	☐	☐	☐	☐
584–84–9	Toluene-2,4-diisocyanate (unspecified isomer)	☑	☐	☐	☐	☐	☐	☐
592–34–7	n-Butyl chloroformate	☑	☐	☐	☐	☐	☐	☐
592–62–1	Methylazoxymethanol acetate	☐	☐	☑	☐	☐	☐	☐
593–60–2	Vinyl bromide	☐	☐	☑	☐	☐	☐	☐
593–74–8	Dimethyl mercury	☑	☐	☑	☐	☐	☑	☐
593–89–5	Methyldichloroarsine	☑	☐	☐	☐	☐	☐	☐
598–14–1	Ethyldichloroarsine	☑	☐	☐	☐	☐	☐	☐
602–87–9	5-Nitroacenaphthene	☐	☐	☑	☐	☐	☐	☐
604–75–1	Oxazepam	☐	☐	☑	☐	☐	☐	☐
606–20–2	2,6-Dinitrotoluene	☐	☐	☑	☐	☐	☑	☐
606–35–9	Trinitroanisole	☐	☐	☐	☐	☐	☐	☑
607–57–8	2-Nitrofluorene	☐	☐	☑	☐	☐	☐	☐
612–83–9	3,3´-Dichlorobenzidine Dihydrochloride	☐	☐	☑	☐	☐	☐	☐
613–35–4	N,N'-Diacetylbenzidine	☐	☐	☑	☐	☐	☐	☐
615–05–4	2,4-Diaminoanisole	☐	☐	☑	☐	☐	☐	☐
615–53–2	N-Methyl-N-nitrosourethane	☐	☐	☑	☐	☐	☐	☐
621–64–7	N-Nitrosodi-n-propylamine	☐	☐	☑	☐	☐	☐	☐
624–83–9	Methyl isocyanate	☑	☐	☐	☐	☐	☐	☐
627–44–1	Diethyl Mercury	☑	☐	☑	☐	☐	☑	☐
628–55–7	isobutyl ether	☐	☐	☐	☐	☐	☐	☑
628–85–3	Dipropyl Mercury	☑	☐	☑	☐	☐	☑	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen: Known	Human Carcinogen: Probable	Reproductive Hazard: Female	Reproductive Hazard: Male	Reproductive Hazard: Fetal	Reactive
628–86–4	Mercury Fulminate	☐	☐	☐	☐	☐	☐	☑
628–96–6	Nitroglycol	☐	☐	☐	☐	☐	☐	☑
630–08–0	Carbon monoxide	☑	☐	☐	☑	☐	☑	☐
636–21–5	o-Toluidine Hydrochloride	☐	☐	☑	☐	☐	☐	☐
638–21–1	Phenylphosphine	☐	☐	☐	☐	☑	☐	☐
674–82–8	Diketene	☑	☐	☐	☐	☐	☐	☐
675–14–9	Cyanuric Fluoride	☑	☐	☐	☐	☐	☐	☐
676–97–1	Methyl phosphonic dichloride	☑	☐	☐	☐	☐	☐	☐
680–31–9	Hexamethylphosphoramide	☐	☐	☑	☐	☐	☐	☐
681–84–5	Tetramethyl orthosilicate	☑	☐	☐	☐	☐	☐	☐
684–16–2	Hexafluoroacetone	☑	☐	☐	☐	☑	☐	☐
684–93–5	N-Methyl-N-nitrosourea	☐	☐	☑	☐	☐	☐	☐
712–68–5	2-Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole	☐	☐	☑	☐	☐	☐	☐
759–73–9	N-Ethyl-N-nitrosourea	☐	☐	☑	☐	☐	☐	☐
765–34–4	Glycidaldehyde	☐	☐	☑	☐	☐	☐	☐
794–93–4	Panfuran S	☐	☐	☑	☐	☐	☐	☐
817–09–4	Trichlormethine (Trimustine hydrochloride)	☐	☐	☑	☐	☐	☐	☐
831–52–7	Sodium picramate	☐	☐	☐	☐	☐	☐	☑
838–88–0	4,4'-Methylene bis(2-methylaniline)	☐	☐	☑	☐	☐	☐	☐
924–16–3	N-Nitrosodi-n-butylamine	☐	☐	☑	☐	☐	☐	☐
930–55–2	N-Nitrosopyrrolidine	☐	☐	☑	☐	☐	☐	☐
993–00–0	Methylchlorosilane	☑	☐	☐	☐	☐	☐	☐
998–40–3	Tributylphosphane	☐	☐	☐	☐	☐	☐	☑
1071–39–2	Diisopropyl Mercury	☑	☐	☑	☐	☐	☑	☐
1116–54–7	N-Nitrosodiethanolamine	☐	☐	☑	☐	☐	☐	☐
1120–71–4	1,3-Propane sultone	☐	☐	☑	☐	☐	☐	☐
1162–65–8	Aflatoxin B	☑	☐	☐	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen: Known	Human Carcinogen: Probable	Reproductive Hazard: Female	Reproductive Hazard: Male	Reproductive Hazard: Fetal	Reactive
1303–00–0	Gallium arsenide	☐	☑	☐	☐	☐	☐	☐
1305–99–3	Calcium phosphide	☐	☐	☐	☐	☐	☐	☑
1309–64–4	Antimony trioxide	☐	☐	☑	☐	☐	☐	☐
1313–60–6	Sodium peroxide	☐	☐	☐	☐	☐	☐	☑
1314–20–1	Thorium Dioxide	☐	☑	☐	☐	☐	☐	☐
1314–62–1	Vanadium pentoxide	☐	☐	☑	☐	☐	☐	☐
1314–84–7	Zinc phosphide	☐	☐	☐	☐	☐	☐	☑
1321–12–6	Mononitrotoluene	☐	☐	☐	☐	☐	☐	☑
1332–21–4	Asbestos	☐	☑	☐	☐	☐	☐	☐
1333–86–4	Carbon black	☐	☐	☑	☐	☐	☐	☐
1337–81–1	vinyl pyridine	☐	☐	☐	☐	☐	☐	☑
1338–23–4	MEK peroxide (butanone peroxide)	☐	☐	☐	☐	☐	☐	☑
1393–62–0	Abrin	☑	☐	☐	☐	☐	☐	☐
1402–68–2	Aflatoxins	☑	☑	☐	☐	☐	☐	☐
1464–53–5	Diepoxybutane	☐	☐	☑	☐	☐	☐	☐
1609–86–5	tert-Butyl isocyanate	☑	☐	☐	☐	☐	☐	☐
1615–80–1	1,2-Diethylhydrazine	☐	☐	☑	☐	☐	☐	☐
1694–09–3	Benzyl violet 4B	☐	☐	☑	☐	☐	☐	☐
1746–01–6	2,3,7,8-Tetrachlorodibenzo-para-dioxin	☐	☑	☐	☐	☐	☐	☐
1836–75–5	Nitrofen	☐	☐	☑	☐	☐	☐	☐
1897–45–6	Chlorothalonil	☐	☐	☑	☐	☐	☐	☐
2068–78–2	Vincristine sulfate	☐	☐	☐	☐	☐	☑	☐
2238–07–5	Diglycidyl ether (DGE)	☐	☐	☐	☐	☑	☐	☐
2243–94–9	Trinitronaphthalene	☐	☐	☐	☐	☐	☐	☑
2270–40–8	Diacetoxyscirpenol	☑	☐	☐	☐	☐	☐	☐
2385–85–5	Mirex	☐	☐	☑	☐	☐	☐	☐
2425–06–1	Captafol	☐	☐	☑	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
2426–08–6	Glycidyl n-butyl ether	☐	☐	☐	☐	☐	☐	☑
2429–74–5	CI Direct Blue 15	☐	☐	☑	☐	☐	☐	☐
2475–45–8	Disperse Blue 1	☐	☐	☑	☐	☐	☐	☐
2487–90–3	Trimethoxysilane	☑	☐	☐	☐	☐	☐	☐
2623–22–5	Monoacetoxyscirpenol	☑	☐	☐	☐	☐	☐	☐
2646–17–5	Oil Orange SS	☐	☐	☑	☐	☐	☐	☐
2691–41–0	Cyclotetramethylenetetranitramine (HMX)	☐	☐	☐	☐	☐	☐	☑
2696–92–6	n-Propyl chloroformate (Nitrosyl chloride)	☑	☐	☐	☐	☐	☐	☐
2699–79–8	Sulfuryl fluoride	☑	☐	☐	☐	☐	☐	☐
2784–94–3	HC Blue No. 1	☐	☐	☑	☐	☐	☐	☐
2937–50–0	Allyl chloroformate	☑	☐	☐	☐	☐	☐	☐
2941–64–2	Ethyl chlorothioformate	☑	☐	☐	☐	☐	☐	☐
2973–10–6	Diisopropyl sulfate	☐	☐	☑	☐	☐	☐	☐
3068–88–0	b-Butyrolactone	☐	☐	☑	☐	☐	☐	☐
3165–93–3	p-Chloro-o-toluidine Hydrochloride	☐	☐	☑	☐	☐	☐	☐
3173–53–3	Cyclohexyl isocyanate	☑	☐	☐	☐	☐	☐	☐
3296–90–0	2,2-Bis(bromomethyl)propane-1,3-diol	☐	☐	☑	☐	☐	☐	☐
3564–09–8	Ponceau 3R	☐	☐	☑	☐	☐	☐	☐
3570–75–0	2-(2-Formylhydrazino)-4-(5-nitro-2-furyl)thiazole	☐	☐	☑	☐	☐	☐	☐
3688–53–7	AF-2 (2-(2-Furyl)-3-(5-nitro-2-furyl)acrylamide)	☐	☐	☑	☐	☐	☐	☐
3697–24–3	5-Methylchrysene	☐	☐	☑	☐	☐	☐	☐
3698–54–2	Tetranitroaniline	☐	☐	☐	☐	☐	☐	☑
3761–53–3	Ponceau MX	☐	☐	☑	☐	☐	☐	☐
3771–19–5	Nafenopin	☐	☐	☑	☐	☐	☐	☐
3795–88–8	5-(Morpholinomethyl)-3-[(5-nitrofurfurylidene)amino]-2-oxazolidinone	☐	☐	☑	☐	☐	☐	☐
4109–96–0	Dichlorosilane	☑	☐	☐	☐	☐	☐	☐
4170–30–3	Crotonaldehyde (2-Butenal)	☑	☐	☐	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
4342–03–4	Dacarbazine	☐	☐	☑	☐	☐	☐	☐
4368–28–9	Tetrodotoxin	☑	☐	☐	☐	☐	☐	☐
4549–40–0	N-Nitrosomethylvinylamine	☐	☐	☑	☐	☐	☐	☐
4732–14–3	Trinitrophenetol	☐	☐	☐	☐	☐	☐	☑
5522–43–0	1-Nitropyrene	☐	☐	☑	☐	☐	☐	☐
5714–22–7	Sulfur Pentafluoride	☑	☐	☐	☐	☐	☐	☐
6055–19–2	Cyclophosphamide	☐	☑	☐	☐	☐	☑	☐
6358–53–8	Citrus Red No. 2	☐	☐	☑	☐	☐	☐	☐
6379–69–7	Trichothecin	☑	☐	☐	☐	☐	☐	☐
6459–94–5	CI Acid Red 114	☐	☐	☑	☐	☐	☐	☐
6484–52–2	Ammonium nitrate	☐	☐	☐	☐	☐	☐	☑
6795–23–9	Aflatoxin M1	☑	☐	☑	☐	☐	☐	☐
6885–57–0	Aflatoxin M2	☑	☐	☐	☐	☐	☐	☐
7220–81–7	Aflatoxin B2	☑	☐	☐	☐	☐	☐	☐
7241–98–7	Aflatoxin G2	☑	☐	☐	☐	☐	☐	☐
7439–92–1	Lead	☐	☐	☑	☑	☑	☑	☐
7439–93–2	Lithium	☐	☐	☐	☐	☐	☐	☑
7439–95–4	Magnesium (powder)	☐	☐	☐	☐	☐	☐	☑
7440–02–0	Nickel, metallic	☐	☐	☑	☐	☐	☐	☐
7440–09–7	Potassium metal	☐	☐	☐	☐	☐	☐	☑
7440–17–7	Rubidium	☐	☐	☐	☐	☐	☐	☑
7440–23–5	Sodium metal	☐	☐	☐	☐	☐	☐	☑
7440–32–6	Titanium powder	☐	☐	☐	☐	☐	☐	☑
7440–38–2	Arsenic and compounds	☐	☑	☐	☐	☐	☐	☐
7440–41–7	Beryllium and beryllium compounds	☐	☑	☐	☐	☐	☐	☐
7440–43–9	Cadmium	☐	☑	☐	☐	☐	☐	☐
7440–46–2	Cesium	☐	☐	☐	☐	☐	☐	☑

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
7440–48–4	Cobalt	☐	☐	☑	☐	☐	☐	☐
7440–58–6	Hafnium powder	☐	☐	☐	☐	☐	☐	☑
7440–66–6	Zinc powder	☐	☐	☐	☐	☐	☐	☑
7440–67–7	Zirconium powder	☐	☐	☐	☐	☐	☐	☑
7446–34–6	Selenium Sulfide	☐	☐	☑	☐	☐	☐	☐
7446–70–0	Aluminum chloride	☐	☐	☐	☐	☐	☐	☑
7481–89–2	Zalcitabine	☐	☐	☑	☐	☐	☐	☐
7496–02–8	6-Nitrochrysene	☐	☐	☑	☐	☐	☐	☐
7550–45–0	Titanium tetrachloride	☑	☐	☐	☐	☐	☐	☐
7553–56–2	Iodine	☑	☐	☐	☐	☐	☐	☐
7580–67–8	Lithium hydride	☐	☐	☐	☐	☐	☐	☑
7601–89–0	Sodium perchlorate	☐	☐	☐	☐	☐	☐	☑
7601–90–3	Perchloric Acid	☑	☐	☐	☐	☐	☐	☑
7637–07–2	Boron trifluoride	☑	☐	☐	☐	☐	☐	☐
7646–69–7	Sodium hydride	☐	☐	☐	☐	☐	☐	☑
7647–01–0	Hydrogen chloride (gas)	☑	☐	☐	☐	☐	☐	☐
7647–19–0	Phosphorus pentafluoride	☑	☐	☐	☐	☐	☐	☐
7664–39–3	Hydrogen fluoride (gas and solutions)	☑	☐	☐	☐	☐	☐	☐
7664–41–7	Ammonia	☑	☐	☐	☐	☐	☐	☐
7664–93–9	Sulfuric acid	☐	☑	☐	☐	☐	☐	☐
7693–27–8	Magnesium hydride	☐	☐	☐	☐	☐	☐	☑
7697–37–2	Nitric acid	☐	☐	☐	☐	☐	☐	☑
7705–07–9	Titanium trichloride	☐	☐	☐	☐	☐	☐	☑
7719–09–7	Thionyl chloride	☐	☐	☐	☐	☐	☐	☑
7719–12–2	Phosphorus trichloride	☑	☐	☐	☐	☐	☐	☑
7722–84–1	Hydrogen peroxide solutions 35% and greater	☑	☐	☐	☐	☐	☐	☑
7723–14–0	Phosphorus white	☐	☐	☐	☐	☐	☐	☑

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
7724–38–1	Tetrodaminotoxin	☑	☐	☐	☐	☐	☐	☐
7724–39–2	Methoxytetrodotoxin	☑	☐	☐	☐	☐	☐	☐
7724–40–5	Ethoxytetrodotoxin	☑	☐	☐	☐	☐	☐	☐
7724–41–6	Deoxytetrodotoxin	☑	☐	☐	☐	☐	☐	☐
7726–95–6	Bromine	☑	☐	☐	☐	☐	☐	☐
7758–01–2	Potassium bromate	☐	☐	☑	☐	☐	☐	☐
7758–19–2	Sodium chlorite	☐	☐	☐	☐	☐	☐	☑
7775–09–9	Sodium chlorate	☐	☐	☐	☐	☐	☐	☑
7775–14–6	Sodium dithionite (Sodium hydrosulphite)	☐	☐	☐	☐	☐	☐	☑
7782–41–4	Fluorine	☑	☐	☐	☐	☐	☐	☐
7782–50–5	Chlorine	☑	☐	☐	☐	☐	☐	☐
7782–65–2	Germane	☑	☐	☐	☐	☐	☐	☐
7782–92–5	Sodamide	☐	☐	☐	☐	☐	☐	☑
7783–06–4	Hydrogen sulfide	☑	☐	☐	☐	☐	☐	☐
7783–07–5	Hydrogen selenide	☑	☐	☐	☐	☐	☐	☐
7783–41–7	Oxygen Difluoride (Fluorine Monoxide)	☑	☐	☐	☐	☐	☐	☐
7783–54–2	Nitrogen trifluoride	☐	☐	☐	☐	☐	☐	☑
7783–61–1	Silicon tetrafluoride	☑	☐	☐	☐	☐	☐	☐
7783–66–6	Iodine pentafluoride	☐	☐	☐	☐	☐	☐	☑
7783–79–1	Selenium hexafluoride	☑	☐	☐	☐	☐	☐	☐
7783–80–4	Tellurium hexafluoride	☑	☐	☐	☐	☐	☐	☐
7783–82–6	Tungsten hexafluoride	☑	☐	☐	☐	☐	☐	☐
7784–21–6	Aluminum hydride	☐	☐	☐	☐	☐	☐	☑
7784–34–1	Arsenic trichloride	☑	☐	☐	☐	☐	☐	☐
7784–42–1	Arsine	☑	☐	☐	☐	☐	☐	☐
7787–71–5	Bromine Trifluoride	☑	☐	☐	☐	☐	☐	☐
7789–09–5	Ammonium dichromate	☐	☐	☐	☐	☐	☐	☑

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen: Known	Human Carcinogen: Probable	Reproductive Hazard: Female	Reproductive Hazard: Male	Reproductive Hazard: Fetal	Reactive
7789–30–2	Bromine pentafluoride	☑	☐	☐	☐	☐	☐	☐
7789–78–8	Calcium hydride	☐	☐	☐	☐	☐	☐	☑
7790–91–2	Chlorine trifluoride	☑	☐	☐	☐	☐	☐	☐
7790–94–5	Chlorosulfonic acid	☑	☐	☐	☐	☐	☐	☐
7790–98–9	Ammonium perchlorate	☐	☐	☐	☐	☐	☐	☑
7791–25–5	Sulfuryl chloride	☑	☐	☐	☐	☐	☐	☐
7803–51–2	Phosphine	☑	☐	☐	☐	☐	☐	☐
7803–52–3	Stibine	☑	☐	☐	☐	☐	☐	☐
8001–35–2	Toxaphen	☐	☐	☑	☐	☐	☐	☐
8001–58–9	Creosotes	☐	☐	☑	☐	☐	☐	☐
8006–19–7	Amatol (ammonoium nitrate/trinitrotoluene mix)	☐	☐	☐	☐	☐	☐	☑
8014–95–7	Oleum (Fuming Sulfuric acid)	☑	☐	☐	☐	☐	☐	☐
8052–42–4	Bitumens	☐	☐	☑	☐	☐	☐	☐
9000–07–1	Carrageenan	☐	☐	☑	☐	☐	☐	☐
9004–66–4	Iron-dextran complex	☐	☐	☑	☐	☐	☐	☐
9004–70–0	Nitrocellulose	☐	☐	☐	☐	☐	☐	☑
9009–86–3	Ricin	☑	☐	☐	☐	☐	☐	☐
9040–12–4	Ricins, D	☑	☐	☐	☐	☐	☐	☐
10025–87–3	Phosphorus oxychloride (Phosphoryl chloride)	☑	☐	☐	☐	☐	☐	☐
10026–04–7	Silicon tetrachloride	☐	☐	☐	☐	☐	☐	☑
10026–24–1	Cobalt sulfate	☐	☐	☑	☐	☐	☐	☐
10028–15–6	Ozone	☑	☐	☐	☐	☐	☐	☐
10035–10–6	Hydrogen bromide (gas)	☑	☐	☐	☐	☐	☐	☐
10043–92–2	Radon-222	☐	☑	☐	☐	☐	☐	☐
10048–13–2	Sterigmatocystin	☐	☐	☑	☐	☐	☐	☐
10049–04–4	Chlorine dioxide	☑	☐	☐	☐	☐	☐	☐
10102–43–9	Nitric oxide	☑	☐	☐	☐	☐	☐	☑

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen: Known	Human Carcinogen: Probable	Reproductive Hazard: Female	Reproductive Hazard: Male	Reproductive Hazard: Fetal	Reactive
10102–44–0	Nitrogen Dioxide	☑	☐	☐	☐	☐	☐	☐
10124–37–5	Calcium nitrate	☐	☐	☐	☐	☐	☐	☑
10294–33–4	Boron tribromide	☑	☐	☐	☐	☐	☐	☐
10294–34–5	Boron Trichloride	☑	☐	☐	☐	☐	☐	☐
10540–29–1	Tamoxifen	☐	☑	☐	☐	☐	☐	☐
10544–72–6	Dinitrogen tetroxide	☑	☐	☐	☐	☐	☐	☐
10595–95–6	N-Nitrosomethylethylamine	☐	☐	☑	☐	☐	☐	☐
11017–04–2	Saxitoxin hydrate	☑	☐	☐	☐	☐	☐	☐
11028–71–0	Concanavalin A	☑	☐	☐	☐	☐	☐	☐
11056–06–7	Bleomycins	☐	☐	☑	☐	☐	☐	☐
11100–45–1	Staphylococcus enterotoxin B	☑	☐	☐	☐	☐	☐	☐
11135–81–2	Potassium sodium alloys, liquid	☐	☐	☐	☐	☐	☐	☑
12030–88–5	Potassium superoxide	☐	☐	☐	☐	☐	☐	☑
12034–12–7	Sodium superoxide	☐	☐	☐	☐	☐	☐	☑
12057–74–8	Magnesium phosphide	☐	☐	☐	☐	☐	☐	☑
12174–11–7	Palygorskite (attapulgite)	☐	☐	☑	☐	☐	☐	☐
12504–13–1	Strontium phosphide	☐	☐	☐	☐	☐	☐	☑
13010–47–4	1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU)	☐	☐	☑	☐	☐	☐	☐
13072–89–4	Anhydroepitetrodotoxin	☑	☐	☐	☐	☐	☐	☐
13256–22–9	N-Nitrososarcosine	☐	☐	☑	☐	☐	☐	☐
13285–84–2	Diacetylanhydrotetrodotoxin	☑	☐	☐	☐	☐	☐	☐
13424–46–9	Lead Azide	☐	☐	☐	☐	☐	☐	☑
13463–39–3	Nickel carbonyl	☑	☐	☐	☐	☐	☑	☐
13463–40–6	Iron, Pentacarbonyl	☑	☐	☐	☐	☐	☐	☐
13463–67–7	Titanium dioxide	☐	☐	☑	☐	☐	☐	☐
13637–63–3	Chlorine pentafluoride	☑	☐	☐	☐	☐	☐	☑
13647–35–3	Trilostane	☐	☐	☐	☐	☐	☑	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
13762–51–1	Potassium borohydride	☐	☐	☐	☐	☐	☐	☑
13863–41–7	Bromine chloride	☑	☐	☐	☐	☐	☐	☐
13909–09–6	1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (Semustine)	☐	☑	☐	☐	☐	☐	☐
14808–60–7	Crystalline Silica	☐	☑	☐	☐	☐	☐	☐
14901–08–7	Cycasin	☐	☐	☑	☐	☐	☐	☐
15245–44–0	Lead styphnate	☐	☐	☐	☐	☐	☐	☑
15475–56–6	Methotrexate sodium	☐	☐	☐	☑	☐	☑	☐
15663–27–1	Cisplatin	☐	☐	☑	☐	☐	☐	☐
15825–70–4	Mannitol hexanitrate (Nitromannite)	☐	☐	☐	☐	☐	☐	☑
16543–55–8	N'-Nitrosonornicotine (NNN)	☐	☑	☐	☐	☐	☐	☐
16842–03–8	Cobalt hydrocarbonyl	☑	☐	☐	☐	☐	☐	☐
16853–85–3	Lithium aluminum hydride	☐	☐	☐	☐	☐	☐	☑
16940–66–2	Sodium borohydride	☐	☐	☐	☐	☐	☐	☑
16949–15–8	Lithium borohydride	☐	☐	☐	☐	☐	☐	☑
16962–07–5	Aluminum borohydride	☐	☐	☐	☐	☐	☐	☑
17014–71–0	Potassium peroxide	☐	☐	☐	☐	☐	☐	☑
17462–58–7	sec-Butyl chloroformate	☑	☐	☐	☐	☐	☐	☐
17878–54–5	Aflatoxin B1, B2A	☑	☐	☐	☐	☐	☐	☐
18540–29–9	Chromium Hexavalent Compounds	☐	☑	☐	☐	☐	☐	☐
18660–81–6	Tetrodotoxin citrate	☑	☐	☐	☐	☐	☐	☐
18883–66–4	Streptozotocin	☐	☐	☑	☐	☐	☐	☐
19287–45–7	Diborane	☑	☐	☐	☐	☐	☐	☐
19624–22–7	Pentaborane	☑	☐	☐	☐	☐	☐	☑
20062–22–0	Hexanitrostilbene	☐	☐	☐	☐	☐	☐	☑
20421–10–7	Aflatoxin G(sub 2a)	☑	☐	☐	☐	☐	☐	☐
20770–41–6	Potassium phosphide	☐	☐	☐	☐	☐	☐	☑
20816–12–0	Osmium Tetroxide	☑	☐	☐	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
20830–81–3	Daunomycin	☐	☐	☑	☐	☐	☐	☐
20859–73–8	Aluminum phosphide	☐	☐	☐	☐	☐	☐	☑
21259–20–1	T2 toxin	☑	☐	☐	☐	☐	☐	☐
22398–80–7	Indium phosphide	☐	☐	☑	☐	☐	☐	☐
22506–53–2	3,9-Dinitrofluoranthene	☐	☐	☑	☐	☐	☐	☐
23214–92–8	Adriamycin	☐	☐	☑	☐	☐	☐	☐
23246–96–0	Riddelliine	☐	☐	☑	☐	☐	☐	☐
24167–76–8	Sodium phosphide	☐	☐	☐	☐	☐	☐	☑
25013–16–5	Butylated hydroxyanisole (BHA)	☐	☐	☑	☐	☐	☐	☐
25321–14–6	Dinitrotoluene	☐	☐	☑	☐	☐	☑	☑
25324–56–5	Stannic phosphide	☐	☐	☐	☐	☐	☐	☑
25962–77–0	trans-2-[(Dimethylamino)methylimino]-5-[2-(5-nitro-2-furyl)-vinyl]-1,3,4-oxadiazole	☐	☐	☑	☐	☐	☐	☐
26134–62–3	Lithium nitride	☐	☐	☐	☐	☐	☐	☑
26148–68–5	A-a-C (2-Amino-9H-pyrido[2,3-b]indole)	☐	☐	☑	☐	☐	☐	☐
26471–62–5	Toluene diisocyanate	☐	☐	☑	☐	☐	☐	☐
26628–22–8	Sodium azide (Hydrazoic acid)	☑	☐	☐	☐	☐	☐	☑
26934–87–2	Mycotoxin HT2	☑	☐	☐	☐	☐	☐	☐
26952–42–1	Trinitroaniline	☐	☐	☐	☐	☐	☐	☑
27208–37–3	Cyclopenta [cd] pyrene	☐	☐	☑	☐	☐	☐	☐
28289–54–5	MPTP (1-Methyl-4-phenyl-1,2,3,6-tetrahydropyridine)	☑	☐	☐	☐	☐	☐	☐
28434–86–8	3,3'-Dichloro-4,4'-diaminodiphenyl ether	☐	☐	☑	☐	☐	☐	☐
29611–03–8	Aflatoxin Ro	☑	☐	☐	☐	☐	☐	☐
29767–20–2	Teniposide	☐	☐	☑	☐	☐	☐	☐
30516–87–1	Zidovudine (AZT)	☐	☐	☑	☐	☐	☐	☐
30525–89–4	Paraformaldehyde	☑	☑	☐	☐	☐	☐	☐
30674–80–7	Methacryloyloxyethyl Isocyanate	☑	☐	☐	☐	☐	☐	☐
32215–02–4	AflatoxinP1	☑	☐	☐	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
33419–42–0	Etoposide	☐	☐	☑	☐	☐	☐	☐
35523–89–8	Saxitoxin	☑	☐	☐	☐	☐	☐	☐
35554–08–6	Saxitoxin hydrochloride	☑	☐	☐	☐	☐	☐	☐
35860–51–6	Dinitroresorcinol	☐	☐	☐	☐	☐	☐	☑
37337–57–8	Staphylococcus enterotoxin A	☑	☐	☐	☐	☐	☐	☐
39156–41–7	2,4-Diaminoanisole Sulfate	☐	☐	☑	☐	☐	☐	☐
42397–64–8	1,6-Dinitropyrene	☐	☐	☑	☐	☐	☐	☐
42397–65–9	1,8-Dinitropyrene	☐	☐	☑	☐	☐	☐	☐
42583–46–0	Aflatoxin B1 Epoxide	☑	☐	☐	☐	☐	☐	☐
51264–14–3	Amsacrine	☐	☐	☑	☐	☐	☐	☐
52819–96–2	Aflatoxin Q1	☑	☐	☐	☐	☐	☐	☐
53597–23–2	abrin A	☑	☐	☐	☐	☐	☐	☐
53597–24–3	Abrin C	☑	☐	☐	☐	☐	☐	☐
54413–15–9	Tritonal	☐	☐	☐	☐	☐	☐	☑
54749–90–5	Chlorozotocin	☐	☐	☑	☐	☐	☐	☐
55803–45–7	Saxitoxin p-bromobenzenesulfonate	☑	☐	☐	☐	☐	☐	☐
57835–92–4	4-Nitropyrene	☐	☐	☑	☐	☐	☐	☐
59122–46–2	Misoprostol	☐	☐	☐	☐	☐	☑	☐
59536–65–1	Polybrominated biphenyls	☐	☐	☑	☐	☐	☐	☐
59865–13–3	Cyclosporin A	☐	☑	☐	☐	☐	☐	☐
60153–49–3	3-(N-Nitrosomethylamino)propionitrile	☐	☐	☑	☐	☐	☐	☐
61740–00–9	Aflatoxin Ro'	☑	☐	☐	☐	☐	☐	☐
62450–06–0	Trp-P-1 (3-Amino-1,4-dimethyl-5H-pyrido[4,3-b]indole)	☐	☐	☑	☐	☐	☐	☐
62450–07–1	Trp-P-2 (3-Amino-1-methyl-5H-pyrido [4,3-b]indole)	☐	☐	☑	☐	☐	☐	☐
64091–91–4	4-(N-Nitrosomethylamino)-1-(3-pyridyl)-1-butanone	☐	☑	☐	☐	☐	☐	☐
65271–80–9	Mitoxantrone	☐	☐	☑	☐	☐	☐	☐
66419–04–3	Ricin D (isoleucine-chain reduced)	☑	☐	☐	☐	☐	☐	☐

Particularly Hazardous Substances

CAS Number order

CAS Number	Chemical	Acutely Toxic	Human Carcinogen		Reproductive Hazard			Reactive
			Known	Probable	Female	Male	Fetal	
66733–21–9	Erionite	☐	☑	☐	☐	☐	☐	☐
67730–10–3	Glu-P-2 (2-Aminodipyrido[1,2-a:3',2'-d]imidazole)	☐	☐	☑	☐	☐	☐	☐
67730–11–4	Glu-P-1 (2-Amino-6-methyldipyrido[1,2-a:3',2'-d]imidazole)	☐	☐	☑	☐	☐	☐	☐
68006–83–7	MeA-a-C (2-Amino-3-methyl-9H-pyrido[2,3-b]indole)	☐	☐	☑	☐	☐	☐	☐
72514–84–2	Ricin D (alanine-chain protein moiety)	☑	☐	☐	☐	☐	☐	☐
75757–64–1	Shiga Toxin	☑	☐	☐	☐	☐	☐	☐
76180–96–6	2-Amino-3-methylimidazo[4,5-f]quinoline (IQ)	☐	☐	☑	☐	☐	☐	☐
76862–65–2	Conotoxin GI	☑	☐	☐	☐	☐	☐	☐
77094–11–2	MeIQ (2-Amino-3,4-dimethylimidazo[4,5-f]quinoline)	☐	☐	☑	☐	☐	☐	☐
77439–76–0	3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone	☐	☐	☑	☐	☐	☐	☐
77500–04–0	MeIQx (2-Amino-3,8-dimethylimidazo[4,5-f]quinoxaline)	☐	☐	☑	☐	☐	☐	☐
79217–60–0	Ciclosporin	☐	☑	☐	☐	☐	☐	☐
81133–24–6	Conotoxin GIV	☑	☐	☐	☐	☐	☐	☐
82952–64–5	Trimetrexate glucuronate	☐	☐	☐	☐	☐	☑	☐
93384–43–1	Botulinum toxin A	☑	☐	☐	☐	☐	☐	☐
93384–44–2	Botulinum toxin B	☑	☐	☐	☐	☐	☐	☐
93384–46–4	Botulinum toxin F	☑	☐	☐	☐	☐	☐	☐
96638–28–7	Ricin A	☑	☐	☐	☐	☐	☐	☐
101043–37–2	Microcystin-LR	☐	☐	☑	☐	☐	☐	☐
102489–05–4	Aflatoxin 495	☑	☐	☐	☐	☐	☐	☐
105650–23–5	PhIP (2-Amino-1-methyl-6-phenylimidazo[4,5-b]pyridine)	☐	☐	☑	☐	☐	☐	☐
105735–71–5	3,7-Dinitrofluoranthene	☐	☐	☑	☐	☐	☐	☐
116355–83–0	Fumonisin B1	☐	☐	☑	☐	☐	☐	☐
1056502–30–5	2-Amino-1-methyl-6-phenylimidazo[4,5-b]pyridine (PhIP)	☐	☐	☑	☐	☐	☐	☐

Appendix 5 PHS SOP Template

Standard Operating Procedures (SOPs) and Guidelines describe safe handling procedures for various chemical hazard classes and some commonly-used chemicals. Chemicals identified as Particularly Hazardous Substances require a customized, laboratory-specific SOP. Reference: UH Chemical Hygiene Plan, Chapter 5.

EHLS has developed a general blank template and several customized SOPs for common use chemicals to help lab personnel maitain adequate information and structure for the dissemination and understanding of how these substances will be handled at the University. Please download the templates on this weblink: https://www.uh.edu/ehls/research-lab/chemical-safety/chemical-sop-template/

Training document page is used to document PI led training for lab specific procedures involving certain chemicals and procedures.

Appendix 6. UH Guideline for Perchloric Acid Usage and Storage

UNIVERSITY of HOUSTON
ENVIRONMENTAL HEALTH & LIFE SAFETY

UH Guideline for Perchloric Acid Usage and Storage

Introduction

Perchloric acid is a strong mineral acid commonly used as a laboratory reagent. It is a clear, colorless liquid with no odor. The University of Houston discourages work with perchloric acid of concentrations greater than 60% without proper engineering controls. However, specific chemical reactions and research protocols may require larger concentrations of perchloric acid. If your research is such your lab-specific SOP must be approved by EHLS prior to procurement. Work with perchloric acid is not permitted without a buddy system. This particular guideline was created by the Environmental Health and Life Safety with the goal of complying with 29 CFR 1910.1450 (e)(3)(i) and educating the campus community in the safe use of perchloric acid.

Purpose and Scope

This guideline present information on how to handle and store perchloric acid safely. All UH Laboratory Personnel who work in labs containing perchloric acid must familiarize themselves with this document. A copy of the signature page, the last page of this document, must be kept by the PI and Designee acknowledging Laboratory Personnel have read this document and are aware of the unique dangers and precautions that must be taken when handling this acid.

Overview of Hazards

Under some circumstances perchloric acid may act as an oxidizer and/or present an explosion hazard. Organic materials are especially susceptible to spontaneous combustion if mixed or in contact with perchloric acid. Under some circumstances, perchloric acid vapors form perchlorates in duct work, which are shock sensitive.

Perchloric acid can be a health hazard if inhaled, ingested or splashed on skin or in eyes. To prevent injury, goggles or a face shield over safety glasses, gloves and an apron over lab coat, must be worn when handling perchloric acid. Symptoms of overexposure include irritation and/or burning of the affected area. Inhalation burns are serious and require immediate medical attention. If perchloric acid is ingested, drink approximately 8 oz. of water and seek medical attention immediately. Do not induce vomiting.

Because of its reactivity hazard, perchloric acid digestions of any size shall always be conducted in a special perchloric acid hood that is equipped with a wash down system. Hoods used for hot digestions must be labeled "Perchloric Acid Hood Only. Organic Chemicals Prohibited." Solvents must never be used or stored in a designated perchloric acid hood.

Using Perchloric Acid (<72%) at Room Temperature

At room temperature, perchloric acid up to concentrations of 72% has properties similar to other strong mineral acids. It is a highly corrosive substance that causes severe burns on contact with the eyes, skin, and mucous membranes. When used under these conditions, perchloric acid reacts as a strong non-oxidizing acid. The following precautions must be taken when using perchloric acid under these conditions:

- Substitute with less hazardous chemicals when appropriate. Use dilute solutions (<60%) whenever possible.

- Conduct operations involving cold perchloric acid in a properly functioning chemical fume hood with current EHLS certification. However, perchloric acid reactions performed with higher concentrations or that involve heat must be used in a designate perchloric acid fume hood.

- Always use impact-resistant chemical goggles, a face shield, neoprene gloves, and a rubber apron when handling perchloric acid.

- When using or storing even dilute perchloric acid solutions avoid contact with strong dehydrating agents (concentrated sulfuric acid, anhydrous phosphorous pentoxide, etc.). These chemicals may concentrate the perchloric acid and make it unstable.

- Always transfer perchloric acid over a sink or other suitable containment in order to catch any spills and afford a ready means of cleanup and disposal.

- Perform all operations on chemically resistant surfaces. Avoid contact with cellulose materials such as wood, paper and cotton. Perchloric acid may become concentrated and cause a fire or explosion.

Using Heated Perchloric Acid (<72%)

Perchloric acid digestions and other procedures performed at elevated temperatures must be done in a specially designed perchloric acid fume hoods. If your research is such EHLS must be contacted immediately prior to procurement.

When heated to temperatures above 150° C perchloric acid (<72% concentration) becomes a strong oxidizer and eventually becomes unstable. Concentrated solutions are very dangerous and

can react violently with many oxidizable substances, such as paper and wood, and can detonate. Vapors may also contaminate work surfaces or ventilation equipment with perchlorate residues, which may form highly unstable compounds, such as metallic perchlorates. These compounds may ignite or detonate under certain conditions.

The following additional precautions shall be followed when heating perchloric acid:

- Lower the fume hood sash as much as possible so that it can function as a physical barrier or use a safety shield to provide splash/splinter protection. Perchloric acid fume hoods must have shatterproof glass.

- Never heat perchloric acid in an oil bath or with an open flame. Electric hot plates, electrically or steam-heated sand baths, heating mantles, or steam baths are preferred. Use explosion proof electrical equipment.

- Avoid allowing hot perchloric acid to come into contact with any organic materials, including paper or wood, because a fire or explosion can occur. Avoid storing these materials in perchloric acid work hoods. Avoid using greases or hoses that are incompatible with perchloric acid.

- Be sure to understand the reaction(s) that can occur when using perchloric acid. Perchloric acid may react violently with many chemicals, including acetic anhydride, alcohol, reducing agents, and many metals.

- In wet digestions with perchloric acid, treat the sample first with nitric acid to destroy easily oxidizable matter.

- Do not distill perchloric acid in a vacuum, because the unstable anhydride may be formed and cause a spontaneous explosion. Protect vacuum sources from perchloric acid/perchlorate contamination. Vacuum pumps must be thoroughly flushed and refilled with Kel-F or Fluorolube.

- Wash down perchloric acid hoods after each use, following operating instructions provided by the manufacturer of the perchloric acid hood.

Anhydrous Perchloric Acid

Use Anhydrous Perchloric Acid in a designated, properly designed perchloric acid hood with a minimum of equipment present. No extraneous chemicals shall be present in the hood. If your research is such EHLS shall be contacted immediately prior to procurement.

Anhydrous perchloric acid (> 85% concentration) is very unstable and can explode when it comes in contact with organic materials. Follow these additional precautions when working with anhydrous perchloric acid.

Allow only authorized experienced Laboratory Personnel to handle anhydrous perchloric acid. These Laboratory Personnel shall be thoroughly familiar with the literature on the acid, this guideline, Chemical hygiene plan and Dress Code Policy. Assure that a second worker is informed of the intended use of the anhydrous perchloric acid. This second worker must be in sound or sight contact with the worker using anhydrous perchloric acid. No one shall ever work alone with anhydrous perchloric acid.

Use a safety blast shield to protect oneself against the effects of a possible explosion.

Use thick gauntlets in addition to PPE previously recommended.

Use only freshly prepared acid. Do not make any more anhydrous perchloric acid than is required for a day/shift.

Perchloric Acid Storage

The quantities of perchloric acid kept in storage must be kept to **a minimum.** Perchloric acid must be stored in its original container within compatible secondary containment, preferably glass or porcelain. Perchloric acid bottle shall be properly labelled as mentioned in 4.5 Labelling and Signage.

Perchloric acid must be separate from other chemicals, but may be stored with other inorganic acids, preferably in a metal cabinet designed for acid/corrosive storage. Perchloric acid must be stored away from organic chemicals, flammable materials and strong dehydrating agents such as sulfuric acid and anhydrous phosphorus pentoxide.

If a bottle containing perchloric acid has turned dark and has crystals forming around the bottom of the bottle, there is a potential explosion hazard. **Do NOT move the bottle. Immediately contact EHLS.**

Perchloric Acid Spills

CLEAN UP SPILLS OF PERCHLORIC ACID ONLY IF YOU HAVE BEEN TRAINED TO DO SO AND THE APPROPRIATE EQUIPMENT IS AVAILABLE! If you need advice, call EHLS.

To clean a spill, neutralize it with soda ash (sodium carbonate) or other appropriate neutralizing agent. Soak up the neutralized spill with an inorganic based absorbent, if possible. Do not use organic materials, such as Kim-wipes or toweling as they may spontaneously ignite upon contact with perchloric acid. If rags or paper towels are in advertently used, wet them with water and place them in a tightly sealed plastic bag. Do NOT use rags, paper towels, or sawdust and then

put them aside to dry out, as such materials may spontaneously ignite. A second neutralization and rinsing of the wetted area is recommended.

Perchloric acid waste must not be mixed with other wastes. It shall be placed into acid resistant containers that are clearly labeled and held for disposal.

LAB-SPECIFIC PROTOCOL/PROCEDURE

(please add lab specific Protocol/Procedure here)

UH CHEMICAL HAZARD-SPECIFIC TRAINING RECORD*

PI Acknowledgement

Name:		E-Mail:	
Signature:		Date:	
Office Phone:		Cell Phone:	

Trained Laboratory Personnel

"I have read and understand the Guideline of Perchloric acid. I agree to fully adhere to its requirements. By signing below, I also acknowledge that I have received hands-on training for use of Perchloric acid."

Last	First	PSID	Email	Signature	Date

*This document, including the signature page with each page initiated by all involved personnel shall be submitted to EHLS either electronically via the ehs@uh.edu or hard copy prior to the procurement of perchloric acid or initiation of any research.

Appendix 7. UH Guideline for Nanomaterials

UNIVERSITY of HOUSTON

UH Guideline for Nanomaterials

Prepared by:

Environmental Health and Life Safety (EHLS)
http://www.uh.edu/ehls/

Revision June 2018

EHLS Phone: 713-743-5858

Table of Contents

1.0 Introduction

The increasing use of nanomaterials in research and development laboratories along with applications in industry are providing breakthroughs for many technologies and solutions for addressing major problems in our society. However, as with all new technologies, the potential health effects of engineered nanomaterials (ENMs) remain uncertain. The aim of this project is to provide practical guidance as to how ENMs must be handled safely in the research laboratory setting in the face of such uncertainty over possible toxic effects.

Currently many government agencies, academic institutions, and industries have issued detailed guidance documents as to how NMs can be monitored, controlled, and handled in different work settings. Only a portion of these practices have been validated by scientific research or reference to peer reviewed literature. Most guidance documents and exposure studies to date have focused primarily on industrial settings, but academic research settings present their own challenges that also need to be addressed. Much of the initial research and development in nanotechnology is still performed in academic research laboratories. In academic laboratories, the quantity of materials used tends to be less than those used in industry, but the variety of nanomaterials used tends to be more diverse. As a result, the potential hazards are also more diverse and exposure monitoring is more challenging. Furthermore, academic practices tend to be less standardized and to vary more from lab to lab and from day to day than typical industrial processes. This means that engineering controls which are commonly used in industry may not be practical to apply in academic laboratory research settings.

The nature of research and training in academic institutions dictates that new students and employees with various backgrounds and levels of training are regularly being introduced into the many diverse laboratory settings. Undergraduate student researchers, graduate students and other laboratory personnel often have minimal formal safety training or are lacking the latest hazard information about such new technological developments. All of these factors make a simple adoption or application of standardized industrial best practices for working with NMs in laboratories difficult.

2.0 Purpose and Scope

This guideline presents information on common laboratory operations involving engineered nanomaterials according to their potential risk of exposure to personnel, which is based on the state of the material and the conditions of use. Controls are provided in the table to minimize exposures. This guide is intended to be used in conjunction with the UH laboratory safety practices (UH Chemical Hygiene Plan, UH General Laboratory Safety Manual or other established guidelines (e.g., Prudent Practices by The National Research Council). All UH Laboratory Personnel who work in labs containing nanomaterials must familiarize themselves with this policy. Laboratory-specific Standard Operating Procedures for nanomaterials must be provided by Principle Investigator (PI) and used to train all the nanomaterial users in his/her laboratory. A copy of the signature page, the last page of this document, must be kept by the PI

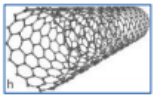
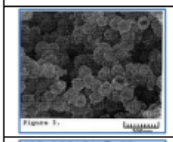
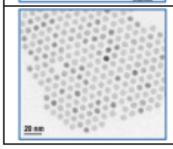
and Designee acknowledging nanomaterial users have read this document and are aware of the unique dangers and precautions that must be taken when handling the nanomaterials.

3.0 Overview of Nanomaterials

Definitions of Nanomaterial: Material or particle with any external dimension in the nanoscale (range 1 nm to 100 nm) or having internal structure or surface structure in the nanoscale.[1,2]

Naturally Occurring Nanomaterial: Particles on the nanoscale occur naturally in the environment. They can also be manufactured and have a variety of commercial applications.

Engineered Nanomaterials (ENMs): An Engineered Nanomaterial is any intentionally produced material with any external dimension in the nanoscale. It is noted that neither 1 nm nor 100 nm is a "bright line" and some materials are considered engineered nanomaterials that fall outside this range. For example, Buckyballs are also included even though they have a size <1 nm. Excluded are materials that are on the nanoscale, but do not have properties that differ from their bulk counterpart and micelles and single polymers.[3]

	Type	Examples
	**Carbon Based**	**Buckyballs or Fullerenes, Carbon Nanotubes*, Dendrimers** *Often includes functional groups like* PEG (polyethylene glycol), Pyrrolidine, N, N-dimethylethylenediamine, imidazole*
	**Metals and Metal Oxides**	**Titanium Dioxide (Titania)**, Zinc Oxide, Cerium Oxide (Ceria), Aluminum oxide, Iron Oxide, Silver, Gold, and Zero Valent Iron (ZVI) nanoparticles**
	**Quantum Dots**	**ZnSe, ZnS, ZnTe, CdS, CdTe, CdSe, GaAs, AlGaAs, PbSe, PbS, InP** *Includes crystalline nanoparticle that exhibits size-dependent properties due to quantum confinement effects on the electronic states (ISO/TS 27687:2008).*

* Carbon Nanotubes are subject to a proposed Recommended Exposure Limit[10] of TWA 7 µg/m^3 due to the risk of developing respiratory health effects.

**Nano-Titanium Dioxide is subject to a proposed Permissible Exposure Limit[11] of TWA 0.3 mg/m^3 due to the risk of developing lung cancer. There are mixed studies regarding TiO2 skin penetration. Some studies indicate TiO2 and ZnO does not pass through the stratum corneum[6,7], while others indicate significant penetration through the skin[8].

Occupational Health and Safety Concerns

1. **Routes of Exposure**
   Exposure to engineered nanomaterials may occur via inhalation and dermal contact depending on use and handling; ingestion is unlikely but possible.
2. **Lack of Information on Full Health Effects**
   With a lack of chronic exposure data and reproductive and developmental toxicity data, a precautionary approach when working with engineered nanomaterials is warranted.
3. **Toxicity**
   Some potential toxic outcomes can be predicted from what we know about ultrafine particles[4] and based on known chemical and structural properties[5]. Nanomaterials have the potential to:
   1. *Deposit in the respiratory tract*. Small airborne particles penetrate deep into the lungs.
   2. *Cross cell membranes*. Some nanomaterials have the ability to cross cell membranes.
   3. *Penetrate healthy intact skin/translocation to other organ systems*. Reports on this topic are mixed; caution is urged until more is known.

4. **Other**
   a. **Catalytic effects**. In general, nanomaterials are not known to have catalytic effects, however, some nanomaterials are specifically engineered to have catalytic properties.
   b. **Fire or explosion**. Nanomaterials are generally not explosive or flammable in small laboratory quantities unless the material is inherently reactive, however some of the synthesis methods may use techniques where fire and explosion are potential hazards.

Exposure Limits

Nanomaterials fall under OSHA General Industry Standards[9]. Established exposure limits for naturally occurring nanomaterials, and detailed information about current state and federal regulations can be found in Appendix C. **Although there are currently no established (legal) exposure limits (US or International)** for Engineered Nanomaterials, NIOSH has developed Recommended Exposure Limits (RELs) for carbon nanotubes **(**TWA 7 µg/m^3) and nano-titanium dioxide **(**TWA 0.3 mg/m^3).

4.0 Planning your research

4.1. Gather Information

Select less-hazardous forms.
Whenever possible, select engineered nanomaterials bound in a substrate or matrix or in water-based liquid suspensions or gels.

Review Safety Data Sheet (SDS), if available.
NOTE: Information contained in some SDSs may not be fully accurate and/or may be more relevant to the properties of the bulk material rather than the nano-size particles. The toxicity of the nanomaterials may be greater than the parent compound.

Review UH Chemical Hygiene Plan for general laboratory safety guidance.

4.2. Determine Potential Risks

Common laboratory operations involving ENMs may be categorized as posing a low, moderate, or high potential exposure risk to researchers depending on the state of the material and the conditions of use. Refer to the Quick Guide for Risk Levels and Control Measures for Nanomaterials. Follow the instructions in this matrix to identify the potential risk of exposure and recommended control measures. Special consideration shall be given to the high reactivity of some nanopowders with regard to potential fire and explosion, particularly if scaling up the process. Consider the hazards of the precursor materials in evaluating the process.

4.3. Develop a Laboratory-specific Standard Operating Procedure (SOP)

A laboratory-specific standard operating procedure (SOP) is a set of written instructions that describes in detail how to perform a laboratory process or experiment safely and effectively. Employing the hierarchy of controls described in Quick Guide for Risk Levels and Control Measures for Nanomaterials, establish an SOP for operations involving nanomaterials.

4.4. Obtain Training and Consultation/Approval

Training. Principal Investigators or Designee must ensure that researchers have both general laboratory safety training and lab-specific training relevant to the nanomaterials and associated hazardous chemicals used in the process/experiment. Laboratory-specific training can include a review of this policy, the relevant Safety Data Sheets (if available), and the lab's Standard Operating Procedure (SOP) for the experiment.
Consultation/Approval. Consult with and seek prior approval of the Principal Investigator prior to procuring or working with nanomaterials.

Notification. If dosing animals with the nanomaterial, follow institution's hazard communication processes for advanced notification of animal facility and cage labeling/management requirements.

5.0 Conducting your research

Controlling potential exposures to nanomaterials involves elimination of highly hazardous materials through substitution, engineering controls, administrative or work practices, and personal protective equipment. The hierarchy of controls are shown in Figure 1. If the nanomaterial cannot be substituted with a less hazardous substance, then engineering controls must be installed to control exposure.

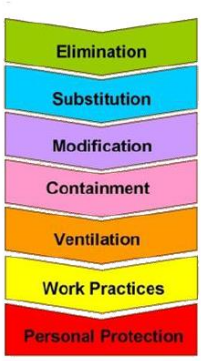


Figure 1
Hierarchy of Controls

5.1 Minimize Exposures

5.1.1 Engineering Controls

CONTROL EXPOSURE WITH EQUIPMENT

Minimize airborne release of ENMs by utilizing one of the following devices:

- **Fume Hoods** When using a fume hood to contain dust or aerosols of nanomaterials, follow good fume hood use practices such as working 6" back from sash, working with sash below 18", removing arms slowly from hoods to prevent dragging out contaminants, and not blocking the lower back slot with equipment.
- **Biosafety Cabinets** Only Class II type A2, B1 or B2 biosafety cabinets which are exhausted into the building ventilation system may be used for nanomaterials work. BSCs that recirculate into the room may not be used. There is recirculation of air inside type A2 and B1 cabinets, so care must be taken not to perform extremely dusty processes in these cabinets as the internal fans of the BSC are not explosion proof. The air in the type B2 cabinet is 100% exhausted and standard amounts of nanomaterials and solvents may be used in this type of enclosure. EHLS shall be consulted when considering a biosafety cabinet for control of nanomaterials.
- **Ventilation for furnaces and reactors** must be provided to exhaust gases generated by this equipment. Unless unfeasible, exhaust gases must be run through a liquid filled bubbler to catch particulate before it enters the building ventilation system. Parts removed from reactors or furnaces for cleaning that may be contaminated with nanomaterial residue shall be repaired or cleaned in a fume hood or other type of exhausted enclosure.
- **Use a glove box or fully-enclosed system.** Where it is not possible to prevent airborne release, such as in grinding operations or in gas phase, use equipment that fully encloses the process. This includes a glove box.
- **Use local capture exhaust hoods.** Do not exhaust aerosols containing engineered nanoparticles into the interior of buildings. Use High-Efficiency Particulate Air (HEPA) filtered local exhaust ventilation (LEV). HEPA-filtered LEV must be located as close to

the possible source of nanoparticles as possible and the installation must be properly engineered to maintain adequate ventilation capture. Use HEPA-filtered local capture exhaust hoods to capture any nanoparticles from tube furnaces, or chemical reaction vessels or during filter replacements.

ENSURE PERFORMANCE AND MAINTENANCE

Laboratory equipment and exhaust systems used with nanoscale materials shall be wet wiped and HEPA vacuumed prior to repair, disposal, or reuse. Make sure fume hoods and any LEV achieves and maintains adequate control of exposure at all times. These systems require regular maintenance and periodic monitoring to ensure controls are working and thorough examination and testing at least once a year.

5.1.2 Administrative Controls

USE SOLUTIONS OR SUBSTRATES

To minimize airborne release of engineered nanomaterials to the environment, nanomaterials are to be handled in solutions, or attached to substrates so that dry material is not released.

LOCATE SAFETY EQUIPMENT

Know the location and proper use of emergency equipment, such as emergency eyewash/safety showers, fire extinguishers, fire alarms, and spill clean-up kits.

USE SIGNS AND LABELS

Restrict access and post signs in area indicating ENM work. When leaving operations unattended, use cautious judgment: 1) Post signs to communicate appropriate warnings and precautions, 2) Anticipate potential equipment and facility failures, and 3) Provide appropriate containment for accidental release of hazardous chemicals.

CLEAN AND MAINTAIN

Line work area with absorbent pad. When working with powders, use antistatic paper and floor sticky mats. Wet wipe and/or HEPA-vacuum work surfaces potentially contaminated with nanoparticles (*e.g.*, benches, glassware, apparatus) at the end of each operation.

MAINTAIN PERSONAL HYGIENE

To avoid potential nanoparticle or chemical exposure via ingestion in area where ENMs are used or stored, do not: consume or store food and beverages, apply cosmetics, or use mouth suction for pipetting or siphoning. Remove gloves when leaving the laboratory in order to prevent contamination of doorknobs or other common use objects such as phones, multiuser computers, etc. Wash hands frequently to minimize potential chemical or nanoparticle exposure through ingestion and dermal contact.

STORE AND LABEL PROPERLY

Store nanomaterials in a well-sealed container. Label all chemical containers with the identity of the contents (do not use abbreviations/ acronyms); include term "nano" in descriptor (*e.g.*, "nano-zinc oxide particles" rather than just "zinc oxide." Include hazard warning and chemical concentration information, if known.

TRANSPORT IN SECONDARY CONTAINMENT

Nanomaterials removed from furnaces, reactors, or other enclosures shall be put in sealed containers with secondary containment for transport to other locations on UH campus. If nanomaterial product from a reactor is bound or adhered to a substrate, the substrate may be removed and put in a transport container. If the nanomaterials product is unbound and easily dispersible (such as in CNT synthesis using aerosolized catalyst), the removal from a reactor shall be done with supplementary exhaust ventilation or a glove bag connected to a HEPA vacuum.

TRANSPORTATION OF NANOMATERIALS OFF-SITE

Transportation of nanomaterials to offsite locations and other universities or laboratories outside of UH may be covered by DOT regulations. Improper packaging and/or transportation could lead to regulatory action and fines. Contact EHLS for procedures to follow for shipping or transporting materials.

5.1.3 Personal Protective Equipment (PPE)

KNOW THE APPLICATIONS AND LIMITS

Many occupational safety and health issues associated with ENM's are not fully understood (*i.e.*, ENM toxicity, exposure metrics, fate and transport, etc.). The same uncertainty exists with how to select the myriad of available types of PPE and effectively use them to minimize the potential hazards associated with employee exposure to ENM hazards.

There is a growing body of evidence resulting from on-going research which indicates that commonly available PPE does have efficacy against specific sizes and types of ENMs. The PPE described within the Quick Guide was selected as a result of a comprehensive review of available guidance and published research available at the time the Guide was developed.

USE THE QUICK GUIDE

The user of this guideline directed to the Quick Guide for a description of the recommended PPE. Note that the referenced PPE increases for each Category consistent with the increasing exposure potential. The basic PPE ensemble described under Category 1 is to be augmented by the specific PPE in Category 2 and Category 3. The user is reminded of the following important issues associated with the safe and effective use of PPE:

Respiratory Protection. Mandatory use of respirators will require full adherence to the requirements of UH respiratory protection program. It is imperative that you consult with EHLS prior to utilizing respiratory protection, even if that use is voluntary.

Gloves and Clothing. Glove material, fabrication process and thickness are significant issues which impact the permeation of ENM's. Consequently, two layers of gloves may be needed for personal protection to be considered adequate. For more information, refer to Table 1.

The selection of dermal PPE for protection against ENM's must also take into account other chemicals which may be part of the ENM matrix or use conditions (*i.e.*, solvents, surfactants, carrier gases, etc.). Dermal PPE manufacturers provide permeation/penetration tables which allow the end user to select dermal PPE based upon performance criteria to specific chemical threats. The technique used to remove gloves (and all PPE) is very important so that any material contaminating the outer surfaces of the PPE does not impact the wearer. Change gloves routinely when using nanomaterials or if contamination is suspected. Keep contaminated gloves in plastic bags or sealed containers with proper label (include term "nano" in descriptor). Wash hands and forearms thoroughly after handling nanomaterials. If contamination of clothing is a concern, use disposable lab coats and dispose of through hazardous waste pickup.

Table 1. Glove Choices for Nanomaterials

Select glove based on compatibility with material and solvents to be used and, if possible, permeability studies for that category of ENM. Recommend wearing gauntlet-type/wrist-length gloves with extended sleeves. The table below contains information on select ENMs and the associated reference.

Nanomaterial / State	Glove Type (Recommendation)
Carbon Nanotubes (CNTs)	Nitrile over Latex*,**
TiO_2 and PT	Latex**, Nitrile, Neoprene***
Graphite	Latex**, Nitrile, Neoprene, Vinyl***

* Consider potential latex allergies in PPE selection.
**Reference: Methner, et. al (NIOSH)
*** Reference: Golanski, et. al (2010)

5.2. Respond to Exposures and Spills

Depending upon the quantity, physical properties, and storage media of nanomaterials in use in the lab, each shall procure the following items as applicable in a nanoparticle spill kit: barricade tape, nitrile gloves, disposable P100 respirators, adsorbent material, wipes, sealable plastic bags, walk-off mat (e.g. Tacki-MatTM). Minor spills or small quantities of nanomaterial can be wiped up using wet wiping for solid material and absorbent wipes for suspensions. Larger spills can be cleaned using a vacuum cleaner specially fitted with a HEPA filter on the exhaust to prevent dispersion into lab air. A log of HEPA vacuum use must be maintained so that incompatible materials are not collected on the HEPA filter. HEPA filter change-out shall be done in a fume hood. Contact the EHLS for cleanup of major nanomaterial spills.
Actions to be taken in the event of a personnel exposure or a spill exposure are also listed as part of "Standard Operating Procedure (SOP) template for Nanomaterials.

5.3. Waste Management

There are no specific EPA regulations that apply to nanomaterial waste. University of Houston are taking a cautious approach and handling nanomaterial waste as hazardous. The following waste management guidance applies to nanomaterial-bearing waste streams consisting of:

- Pure nanomaterials (e.g., carbon nanotubes)
- Items contaminated with nanomaterials (e.g., wipes/PPE)
- Liquid suspensions containing nanomaterials
- Solid matrixes with nanomaterials that are friable or have a nanostructure loosely attached to the surface such that they can reasonably be expected to break free or leach out when in contact with air or water, or when subjected to reasonably foreseeable mechanical forces.

The guidance does not apply to nanomaterials embedded in a solid matrix that cannot reasonably be expected to break free or leach out when they contact air or water, but would apply to dusts and fines generated when cutting or milling such materials.
Nanomaterial – bearing waste streams shall not be placed into the regular trash or down the drain. If there are questions, the EHLS shall be called for a waste determination.

Specific waste management guidance is as follows;
Paper, wipes, PPE and other items with loose contamination are collected in a plastic bag or other sealable container stored in a laboratory hood. When the bag is full, close it, and place it into a second plastic bag or other sealable container. Label the outer bag with the hazardous waste tag. The content section of the label must indicate that it contains nano sized particles and indicate what they are.

Characterize the other hazards of the waste: currently the disposal requirements for the base materials are considered first when characterizing these materials. If the base material is toxic, such as silver or cadmium, or the carrier is a hazardous waste, such as a flammable solvent or acid, they shall be identified on the red tag. Many nanoparticles may also be joined with toxic metals or chemicals. Bulk carbon is considered a flammable solid, so even carbon based nanomaterials shall be collected for determination as hazardous waste characteristics.

Manage waste streams containing ENMs according to the hazardous waste program requirements on UH Waste Manual. Until more information is available, assume ENM containing wastes to be hazardous waste unless they are known to be non-hazardous. Recommended management methods for typical research waste streams containing nanomaterials are described in Table 2.

Table 2. Recommended Nanomaterial waste management methods by stream.

Waste Stream	Management Method
Solid • Dry ENM product • Filter media containing ENMs • Debris / dust from ENMs bound in matrix	1. Manage according to UH Hazardous Waste Program. 2. Label nanomaterial waste containers at all times. Specify the nanomaterial and its hazard characteristic (or the hazard characteristic of the parent material) on container labels; label information to contain the word "nano" as a descriptor. 3. Keep containers closed at all times when not in use. 4. Maintain containers in good condition and free of exterior contamination. 5. Collect waste in rigid container with tight fitting lid.
Liquid • Suspensions containing ENMs	1. Manage according to UH Hazardous Waste Program. 2. Label nanomaterial waste containers at all times. Specify the nanomaterial and its hazard characteristic (or the hazard characteristic of the parent material) on container labels; label information to contain the word "nano" as a descriptor. 3. Keep containers closed at all times when not in use. 4. Maintain containers in good condition and free of exterior contamination. 5. Indicate both the chemical constituents of the solution and their hazard characteristics, and the identity and approximate percentage of ENMs on container labels. 6. Use leak proof containers that are compatible with all contents. 7. Place liquid waste containers in secondary containment and segregate from incompatible chemicals during storage.
Laboratory trash with trace nanomaterials • PPE • Sticky mats • Spill clean-up materials	• Manage according to UH Hazardous Waste Program. • Label nanomaterial waste containers at all times. Specify the nanomaterial and its hazard characteristic (or the hazard characteristic of the parent material) on container labels; label information to contain the word "nano" as a descriptor. • Keep containers closed at all times when not in use. • Maintain containers in good condition and free of exterior contamination. • Dispose of in double clear plastic bags, folded over and taped at the neck. • Avoid rupturing the bags during storage and transport.
Solid Matrix embedded with nanomaterials (intact and in good condition)	1. Consult with your EHLS, as these materials may be non-hazardous.

6.0 Quick Guide for Risk Levels and Control Measures for Nanomaterial

Purpose

This Quick Guide categorizes common laboratory operations involving engineered nanomaterials according to their potential risk of exposure to personnel, which is based on the state of the material and the conditions of use. Controls are provided in the table to minimize exposures. This guide is intended to be used in conjunction with the UH laboratory safety practices or other established guidelines.

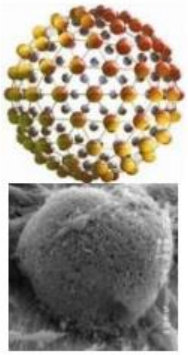
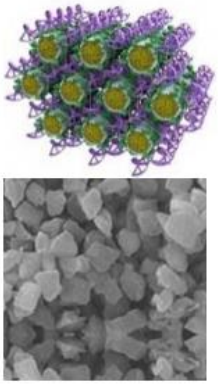
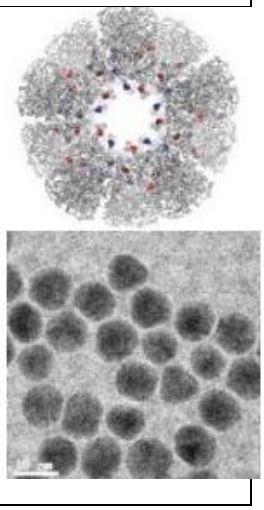
Instructions

Follow these steps to create a Standard Operating Procedure:

- Step 1. Determine your risk level
- Step 2. Identify the controls needed
- Step 3. Develop a Standard Operating Procedure

Below are tables to assist you in completing each step. If your research falls in between two risk categories, consider employing the higher level control.

Step 1. Determine your risk level

Risk Level	Material State or Type of Use	Examples	
Category 1 Lower Exposure Potential	**Material State** No potential for airborne release (when handling) • Solid: Bound in a substrate or matrix • Liquid: Water-based liquid suspensions or gels • Gas: No potential for release into air (when handling) **Type of Use** • No thermal or mechanical stress	• Non- destructive handling of solid engineered nanoparticle composites or nanoparticles permanently bonded to a substrate	
Category 2 Moderate Exposure Potential	**Material State** Moderate potential for airborne release (when handling) • Solid: Powders or Pellets • Liquid: Solvent-based liquid suspensions or gels • Air: Potential for release into air (when handling) **Type of Use** • Thermal or mechanical stress induced	• Pouring, heating ,or mixing liquid suspensions (e.g., stirring or pipetting), or operations with high degree of agitation involved (e.g., sonication) • Weighing or transferring powders or pellets • Changing bedding out of laboratory animal cages	
Category 3 Higher Exposure Potential	**Material State** High potential for airborne release (when handling) • Solid: Powders or Pellets with extreme potential for release into air • Gas: Suspended in gas	• Generating or manipulating nanomaterials in gas phase or in aerosol form • Furnace operations • Cleaning reactors • Changing filter elements • Cleaning dust collection systems used to capture nanomaterials • High speed abrading / grinding nanocomposite materials	

Step 2. Identify the controls needed

Use the table below to identify the controls needed to work with the risk level of your nanomaterial (Category 1, 2, or 3).

Risk level	Controls	
Category 1 Low Exposure Potential	Engineering	• **Fume Hood or Biosafety Cabinet.** Perform work with open containers of nanomaterials in liquid suspension or gels in a laboratory-type fume hood or biosafety cabinet, as practical.
	Work Practices	• **Storage and labeling.** Store in sealed container and secondary containment with other compatible chemicals. Label chemical container with identity of content (include the term "nano" in descriptor). • **Preparation.** Line workspace with absorbent materials. • **Transfer in secondary containment.** Transfer between laboratories or buildings in sealed containers with secondary containment. • **Housekeeping.** Clean all surfaces potentially contaminated with nanoparticles (i.e., benches, glassware, apparatus) at the end of each operation using a HEPA vacuum and/or wet wiping methods. DO NOT dry sweep or use compressed air. • **Hygiene.** Wash hands frequently. Upon leaving the work area, remove any PPE and wash hands, forearms, face, and neck. • **Notification.** Follow institution's hazard communication processes for advanced notification of animal facility and cage labeling/management requirements if dosing animals with the nanomaterial
	PPE	• **Eye protection**. Wear proper safety glasses with side shields (for powders or liquids with low probability for dispersion into the air) • **Face protection**. Use face shield where splash potential exists. • **Gloves**. Wear disposable gloves to match the hazard, including consideration of other chemicals used in conjunction with nanomaterials (refer to Table 1. Glove Choices for Nanomaterials) • **Body protection.** Wear laboratory coat and long pants (no cuffs). • **Closed toe shoes.**
Category 2 Moderate Exposure Potential	Engineering	• **Fume Hood, Biosafety Cabinet, or Enclosed System.** Perform work in a laboratory-type fume hood, biosafety cabinet* (must be ducted if used in conjunction with volatile compounds), powder handling enclosure, or enclosed system (i.e., glove box, glove bag, or sealed chamber).
	Work Practices	• **Category 1 Work Practices.** Follow all work practices listed for Category 1. • **Access.** Restrict access. • **Signage.** Post signs in area. • **Materials.** Use antistatic paper and/or sticky mats with powders.
	PPE	• **Category 1 PPE.** Wear all PPE listed for Category 1. • **Eye protection.** Wear proper chemical splash goggles (for liquids with powders with moderate to high probability for dispersion into the air). • **Gloves.** Wear two layers of disposable, chemical-protective gloves. • **Body protection.** Wear laboratory coat made of non-woven fabrics with

		elastic at the wrists (disposable Tyvek®-type coveralls preferred). • **Closed toe shoes.** Wear disposable over-the-shoe booties to prevent tracking nanomaterials from the laboratory when working with powders and pellets. • **Respiratory Protection.** If working with engineering controls is not feasible, respiratory protection may be required. Consult an EHLS professional for more information (i.e., N95 respirator, or one fitted with a P-100 cartridge).
Category 3 High Exposure Potential	Engineering	• **Enclosed System.** Perform work in an enclosed system (i.e., glove box, glove bag, or sealed chamber).
	Work Practices	• **Category 2 Work Practices.** Follow all work practices listed for Category 2.
	PPE	• **Category 2. PPE** Wear all PPE listed for Category 2. • **Body protection.** Wear disposable Tyvek®-type coveralls with head coverage. • **Respiratory Protection.** If working with engineering controls is not feasible, respiratory protection may be required. Consult EHLS for more information (i.e., N95 respirator, or one fitted with a P-100 cartridge).

Step 3. Develop a Standard Operating Procedure Complete "Standard Operating Procedures (SOP) for the Laboratory Use of Nanomaterials".

7.0 Reference

1 Lövestam, G., Rauscher, H., et al. (2010). Considerations on a Definition of Nanomaterial for Regulatory Purpose. *Joint Research Centre (JRC) Reference Reports*. Luxembourg, European Union [ISO TS 80004-1]
2 Council for Science and Technology Nanosciences and Nanotechnologies. (2007). A Review of Government's Progress on Its Policy Commitments. *Nano Review* (11). London.
3 Good Nano Guide. (2007, March 13). *What are nanomaterials?* Retrieved June 16, 2011 from http://goodnanoguide.org/tiki-index.php?page=What+are+nanomaterials; and American Chemistry Council, Nanotechnology Panel. (2007, March 13). *Consideration for a Definition for Engineered Nanomaterials*. Retrieved June 16, 2011 from http://www.americanchemistry.com
4 Peters, A., Ruckerl, R., et al. (2011). Lessons From Air Pollution Epidemiology for Studies of Engineered Nanomaterials. *Journal of Occupational and Environmental Medicine* 53 (6 Supplement): S8-S13.
5 Castranova, V. (2011). Overview of Current Toxicological Knowledge of Engineered Nanoparticles. *Journal of Occupational and Environmental Medicine* 53 (6 Supplement): S14-S17.
6 Nohynek, G. J., EDufour, E.K., et al. (2008). Nanotechnology, Cosmetics and the Skin: Is There a Health Risk? *Skin Pharmacology and Physiology* 21(3): 136-149.
7 Sadrieh, N., Wokovich, A.M., et al. (2010). Lack of Significant Dermal Penetration of Titanium Dioxide from Sunscreen Formulations Containing Nano- and Submicron-Size TiO2 Particles. *Toxicological Sciences* 115 (1): 156-166.
8 Wu, J., Liu, W., et al. (2009). Toxicity and penetration of TiO2 nanoparticles in hairless mice and porcine skin after subchronic dermal exposure. *Toxicology Letters* 191 (1): 1-8.
9 OSHA. *Nanotechnology Standards*. http://www.osha.gov/dsg/nanotechnology/nanotech_standards.html

University Web Sites with Guidelines for Working with Nanomaterials

MIT. Potential Risks of Nanomaterials and How to Safely Handle Materials of Uncertain Toxicity. Available at http://ehs.mit.edu/site/content/nanomaterials-toxicity

MIT. Best Practices for Handling Nanomaterials in Laboratories. Available at https://ehs.mit.edu/site/sites/default/files/files/University_Best_Practices.pdf

California Nanosafety Consortium of Higher Education. Nanotoolkit Working Safely with Engineered Nanomaterials in Academic Research Settings. Available at http://innovation.luskin.ucla.edu/sites/default/files/nano%20toolkit%202012%200419%20updated.pdf

8.0 Standard Operating Procedures Template for Nanomaterials

UNIVERSITY of HOUSTON
ENVIRONMENTAL HEALTH & LIFE SAFETY

Joe Tremont
Director for Environmental Health and Safety
Phone: 713-743-5861
Fax: 713-743-8035

Chemical Name: Nanomaterials

STANDARD OPERATING PROCEDURES

This is an SOP template and is not complete until: 1) lab specific information is entered into the box below 2) lab specific protocol/procedure is added to the protocol/procedure section and 3) SOP has been signed and dated by the PI and relevant lab personnel.

According to the Safety Data Sheet (SDS) for Nanomaterials special precautions must be taken when working with this chemical. This operating procedure briefly describes the use of the equipment and supplies maintained at the facility, procedures that must be followed, and the responsibilities of personnel when working in these facilities. Amend SOP to reflect changes in procedure, equipment, etc. Do not conduct experiments, even pilot studies, which are not described in this approved SOP. It is essential that all personnel follow the appropriate procedures outlined in this SOP. **Please provide the SDS associated with this chemical.**

PI Acknowledgement

Name:	
Dept:	
PSID:	
Date:	

	1. PI Responsibilities (Please initial before each responsibility below.)	
	The Principal Investigator is responsible for training employees using the chemical. The training must include a discussion of the known and potential hazards and an explanation of the relevant policies, techniques and procedures including the proper use of personal protective equipment and containment equipment.	
	Employees shall be trained initially and then annually thereafter. Their knowledge, competence and practices must be evaluated and documented.	
	Implement a safety program and include this information in the chemical hygiene plan.	

	Limit access to authorized users.
	Minimize the possibility of direct skin or eye contact with the drug or inadvertent ingestion/inhalation.
	Transportation of the chemical within the facility shall be performed using a sealed non-breakable secondary container.
	Develop Standard Operating Procedures (SOP) for delivery and storage of the chemical. The SOP must have a contingency plan for broken or leaking bottles.
	Properly label containers and any secondary containers of the chemical.
	Provide SDS via email to ehs@uh.edu

2. Chemical Information

Nanomaterials are materials having one or more external dimensions, or an internal structure of 100 nm or less, which could exhibit novel characteristics compared to the same material without nanoscale features.

Special Circumstances of Use:
(Use this section to describe the circumstances of use, including the types of nanomaterials covered by this SOP, the shape and size of particles/fibers, and chemical composition. Include the approximate total mass that will be handled at a time as well as the frequency of use, along with a description of steps (such as synthesis, weighing, etc.) **Please provide a 1-2 sentence brief description of the process. Indicate if aerosols are likely to be created.**

Material State and Conditions of Use ***(check all that apply***	Frequency (check one):	Duration per experiment:
Nanomaterials are handled in/as: ☐ dry particles (powders / pellets) ☐ suspension / gels ☐ gaseous phase	☐ one time ☐ daily ☐ weekly ☐ monthly ☐ other:	_____ minutes; or _____ hours

Risk Level(check one):

☐ **Category 1**: low potential for exposure
☐ **Category 2**: moderate potential for exposure
☐ **Category 3**: high potential for exposure

Potential Hazards. Identify potential chemical and safety hazards using the safety data sheet (SDS) for the nanomaterial or parent compound. The toxicity of the nanomaterials may be greater than the

parent compound. Special consideration must be given to the high reactivity of some nanopowders with regard to potential fire and explosion, particularly if scaling up the process. Consider the hazards of any precursor materials in evaluating the process. For more information, refer to the section on "planning your research".

3. Engineering Controls

If aerosols may be produced, nanomaterials (and any suspensions of nanomaterials) must be handled in a chemical fume hood, exhausted biological safety cabinet with negative pressure ductwork, or other exhausted enclosure. Aerosols may be produced during any open handling of dry powder, and during open or pressurized manipulations of suspensions.

Controls beyond those described above are warranted when aerosol generation of nanomaterials will be extensive, or will involve PHS parent materials or tubular or fibrous-shaped nanomaterials. These controls might include a higher level of containment and/or HEPA-filtration or other cleaning of exhaust.

Indicate engineering device(s) to be utilized. Note: if work cannot be conducted with appropriate engineering controls, consult with an EHLS professional.

☐ **Fume hood** *(laboratory-type)*
☐ **Biosafety cabinet** *(must be ducted if used in conjunction with volatile compounds)*
☐ **Enclosed system** *(i.e., glove box, glove bag, or sealed chamber)*
☐ **Powder handling enclosure**
☐ **other:**

4. Work Practice Controls

The following controls will be implemented *(check all that apply):*

☐ Category 1 work practices

- **STORE** in sealed container with secondary containment with other compatible chemicals
- **LABEL** chemical container with the identity of contents and include term "nano" as descriptor
- **TRANSFER** in sealed container with secondary containment
- **PREPARE** work space by lining with absorbent materials
- **CLEAN** all surfaces potentially contaminated with nanoparticles (e.g., benches, glassware, apparatus) at the end of each operation using a HEPA vacuum and/or wet wiping methods.
- **WASH** hands frequently. Upon leaving the nanomaterial work area, remove any PPE worn and wash hands, forearms, face, and neck.
- **NOTIFY** in advance of animal facility and cage labeling / management

☐ Category 2 work practices

- **FOLLOW** all work practices listed for Category 1.
- RESTRICT ACCESS.
- POST signs in area
- **USE** antistatic paper and/or sticky mats with powders.

☐ Category 3 work practices

- **FOLLOW** all work practices listed for Category 2.

requirements if dosing animals with nanomaterial

☐**Approvals Required**. Identify tasks that require prior approval by the principal investigator / laboratory supervisor before performing:

☐**Other**. Describe any additional work practices specific to the experiment / process:

5. Personal Protective Equipment (PPE)

PERSONAL PROTECTIVE EQUIPMENT (PPE). INDICATE THE PPE TO BE UTILIZED *(check all that apply):*

Body Protection:
- ☐ Long pants (no cuffs)
- ☐ Laboratory coat *made of standard materials*
- ☐ Laboratory coat *made of non-woven fabrics with elastics at wrists (i.e., Tyvek®)*
- ☐ Coveralls (disposable) with head coverage *(i.e., Tyvek®)*

Eye / Face Protection:
- ☐ Safety glasses with side shields
- ☐ Chemical splash goggles
- ☐ Face shield

Hand Protection:
- ☐ Latex
- ☐ Nitrile
- ☐ Neoprene
- ☐ Vinyl
- ☐ Other:

Foot Protection:
- ☐ Closed toe shoes
- ☐ Over-the-shoe booties

Other:
- ☐ Respiratory Protection*
- ☐ Other:

6. Storage

- Nanomaterials must be in sealed shatter-resistant containers during transportation. If the container is not shatter-resistant, use a secondary container.
- Containers must be labeled with nanomaterial name (or composition) and approximate particle size, along with any known hazard warnings.
- If the material may be flammable, reactive, or explosive, keep away from heat and open flame.

Keep these powders away from any incompatible materials.

List if any specific incompatibles.

7. Accident and Spill Procedures

Location of nearest emergency equipment:

Item:	Location
Eyewash/Safety Shower	
First Aid Kit	
Chemical Spill Kit	
Fire Extinguisher	
Telephone	

Personnel Exposure procedures

1. Flush contamination from eyes/skin using the nearest emergency eyewash /shower for a minimum of 15 minutes. Remove any contaminated clothing.
2. Take copy of MSDS(s) of chemical(s) when seeking medical treatment.
3. Report potential exposures to your Principal Investigator/Laboratory Supervisor.
4. File an incident report with your institution.

Spill Response procedures

1. **Notify.** Alert workers near spill to avoid entering the area. Post signs in area or on door of lab. Eliminate sources of ignition. Report spill to your Principal Investigator/Lab Supervisor.

2. **Assess.** Are you able to cleanup spill yourself?

If YES *Proceed with* ***Spill Cleanup*** *if it is a small spill (i.e., 30 mL), you are knowledgeable about the hazards of the spill, it can be cleaned up within 15 minutes, and an appropriate spill kit is available.*

If NO *Obtain spill assistance. Contact EHLS.*

3. **Cleanup Spill.** Wear existing PPE (NOTE: Respiratory protection may be required if spill / release is outside the engineering control device).

For powders:

- *Use a dedicated, approved HEPA vacuum whose filtration effectiveness has been verified.*
- *Do not sweep dry nanoparticles or use compressed air.*

- *Consider possible pyrophoric hazards associated with vacuuming up nanoparticles.*
- *Wet wipe using damp cloths with soaps or cleaning oils, or commercially available wet or electrostatic microfiber cleaning cloths. Consider possible reactivity of nanoparticles with the wipe solvent.*

For liquid dispersions:

- *Apply absorbent material (appropriate for the solvent in the dispersion) to liquid spill.*
-

4. **Dispose.** Dispose of used cleaning materials and wastes as hazardous waste.

5. **Report**. File incident to EHLS.

8. Waste Disposal

Indicate the nanomaterial waste management procedures to be utilized.

	Waste Stream	Management Method
☐	Solid • Dry ENM product • Filter media containing ENMs • Debris / dust from ENMs bound in matrix	6. Manage according to UH Hazardous Waste Program. 7. Label nanomaterial waste containers at all times. Specify the nanomaterial and its hazard characteristic (or the hazard characteristic of the parent material) on container labels; label information to contain the word "nano" as a descriptor. 8. Keep containers closed at all times when not in use. 9. Maintain containers in good condition and free of exterior contamination. 10. Collect waste in rigid container with tight fitting lid.
☐	Liquid • Suspensions containing ENMs	8. Manage according to UH Hazardous Waste Program. 9. Label nanomaterial waste containers at all times. Specify the nanomaterial and its hazard characteristic (or the hazard characteristic of the parent material) on container labels; label information to contain the word "nano" as a descriptor. 10. Keep containers closed at all times when not in use. 11. Maintain containers in good condition and free of exterior contamination. 12. Indicate both the chemical constituents of the solution and their hazard characteristics, and the identity and approximate percentage of ENMs on container labels. 13. Use leak proof containers that are compatible with all contents. 14. Place liquid waste containers in secondary containment and segregate from incompatible chemicals during storage.
☐	Laboratory trash with trace nanomaterials • PPE • Sticky mats • Spill clean-up	• Manage according to UH Hazardous Waste Program. • Label nanomaterial waste containers at all times. Specify the nanomaterial and its hazard characteristic (or the hazard characteristic of the parent material) on container labels; label information to contain the word "nano" as a descriptor.

	materials	• Keep containers closed at all times when not in use. • Maintain containers in good condition and free of exterior contamination. • Dispose of in double clear plastic bags, folded over and taped at the neck. • Avoid rupturing the bags during storage and transport.
☐	Solid Matrix embedded with nanomaterials (intact and in good condition)	2. Consult with your EHLS, as these materials may be non-hazardous.

Describe Laboratory-specific waste management procedures here (if applicable):

10. Lab-specific Protocol/Procedure (Please add lab specific Protocol/Procedure here or attach additional pages as necessary)

11. EHLS Policy Requires

EHLS policy requires that all chemical hazards must be clearly identified. If you have any questions regarding risk assessment and SOP development, contact the EHLS office 713-743-5858 or ehs@uh.edu

This SOP must be supplemented with the UH Chemical Hygiene Plan and must include special practices when working with nanomaterial and the SDS must be accessible. Also, all laboratory personnel must be familiar with safe handling practices (i.e., training with proof of training).

PI Acknowledgement

By signing this form the individual certifies that the information provided is true and correct to the best of their knowledge.

Name:		E-Mail:	
Signature:		Date:	
Office Phone:		Cell Phone:	

Trainer Acknowledgement

"I acknowledge that I have provided below training(s) to nano material users listed in 'Trained Laboratory

Personnel'."

(check all the apply)

☐ **Review** the UH Nanomaterial Guideline

☐ **Review** the SDS for the nanomaterial(s), *if available*

☐ **Review** the SDS for other chemicals involved in the experiment/process

☐ **Review** this SOP

Name:		E-Mail:	
Signature:		Date:	

Trained Laboratory Personnel

"I have read and understand this SOP. I agree to fully adhere to its requirements. By signing below, I also acknowledge that I have received trainings for use of nanomaterials."

Last	First	PSID	Email	Signature	Date

*This document, including the signature page with signatures by all involved personnel shall be maintained by the Principal Investigator or Designee, and be submitted to EHLS either electronically via the ehs@uh.edu or hard copy upon request.

Appendix 8. UH Guideline for Pyrophoric Water-reactive Chemicals

UNIVERSITY of HOUSTON

UH Guideline for Pyrophoric/Water-Reactive

Prepared by:

Environmental Health and Life Safety (EHLS)
http://www.uh.edu/ehls/

Revision June 2018

EHLS Phone: 713-743-5858

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1.0 Introduction

Pyrophoric liquids and solids spontaneously ignite within 5 minutes after coming into contact with air. Water-reactive chemicals become spontaneously flammable or emit flammable gases in potentially dangerous quantities upon contact with water, steam or moisture. The reactive nature of these chemicals makes proper training, handling, storage, and control measures critical to ensuring the health and safety of researchers. Failure to comply with safety measures can lead to fires, explosions, property damage and serious injuries or even death. This document provides guidelines for the safe use of pyrophoric and water-reactive chemicals in laboratories.

Any handling of a pyrophoric/water reactive material is high risk and must be controlled with adequate system design, direct supervision and training. These tasks are two person tasks and workers shall not work alone.

2.0 Examples of Pyrophoric/Water Reactive Materials

- Grignard Reagents: RMgX (R=alkyl or aryl, X=halogen)
- Metal alkyls and aryls: Alkyl lithium compounds; tert-butyl lithium
- Metal carbonyls: Lithium carbonyl, nickel tetracarbonyl
- Group I (Alkali) metals: Lithium, potassium, sodium, sodium-potassium alloy (NaK), rubidium, cesium, francium
- Metal powders (finely divided): Cobalt, iron, zinc, zirconium
- Metal hydrides: Sodium hydride, lithium aluminum hydride
- Nonmetal hydrides: Diethylarsine, diethylphosphine
- Non-metal alkyls: R_3B, R_3P, R_3As; tetramethyl silane, tributyl phosphine
- White and red phosphorus

3.0 Purpose and Scope

This guideline present information on how to handle and store pyrophorics/water reactives. All UH Laboratory Personnel who work in laboratories containing pyrophorics/water reactives must familiarize themselves with this document. A copy of the signature page, the last page of this document, must be kept by the PI and Designee acknowledging Laboratory Personnel have read this document and are aware of the unique dangers and precautions that must be taken when handling the pyrophorics/water reactives.

4.0 Overview of Hazards Control Methods

The main hazard associated with pyrophoric/water-reactive chemicals is **fire** upon contact with air or moisture in various environments including air, oxygen, water, or other chemicals with reactive hydroxyl groups. The high level of reactivity associated with these chemicals requires them to be handled in inert atmospheres, free of ignition sources.

The hazards associated with these chemicals is exacerbated by the fact that many are stored in highly flammable solvents (e.g., diethyl ether, hexane, pentane, tetrahydrofuran, etc.), further

increasing the risk and severity of fires. In addition to reactivity and flammability, many of these chemicals are also classified as acutely toxic, corrosive, reproductive toxins, peroxide-forming agents or capable of damaging the liver, kidneys, and central nervous system.

5.0 Controlling the Hazards

BEFORE working with pyrophoric/water reactive reagents, consult with your Principal Investigator (PI) to receive approval before working with highly hazardous materials, read the relevant Safety Data Sheets (SDS), technical bulletins, and guidance documents to understand how to mitigate the hazards. The SDS must be reviewed before using an unfamiliar chemical and periodically as a reminder. Perform a hazard analysis and identify the potential failures or weak points in your experimental design. Be prepared to handle accidents.

Users of reactive materials must be trained in proper lab technique stated in Standard Operating Procedures (SOP) and be able to demonstrate proficiency. Do not work alone or during off hours, when there are few people around to help. Always wear the appropriate personal protective equipment.

Remove all excess and nonessential chemicals and equipment from the fume hood or glove box where pyrophoric/water reactive chemicals will be used. This will minimize the risk if a fire occurs. Keep combustible materials, including paper towels and Kim wipes, away from reactive reagents.

Keep the amount of pyrophoric/water reactive material present in your lab to the smallest amount practical. Use and handle the smallest quantity practical. It is better to do multiple transfers of small volumes than attempt to handle larger quantities (greater than about 20 mL). Alternatively, an appropriately engineered system, capable of safely handling the larger quantity must be designed, tested and properly used.

6.0 Personal Protective Equipment

The following must be worn at all times when handling pyrophoric chemicals and when working with glassware (such as a Schleck flask) that contains pyrophoric chemicals.

- Long pants or clothing that covers the body to the ankles and closed-toe solid top shoes must be worn when working with these compounds. A flame resistant lab coat must be worn when working with pyrophoric chemicals. Lab coats need to be buttoned and fit properly to cover as much skin as possible. Clothing, shirt and pants, must be cotton, wool, or another natural fiber.
- Safety glasses or goggles that meet the ANSI Z.87.1 1989 standard must be worn whenever handling pyrophoric chemicals. When there is the potential for splashes, goggles must be worn under a face shield. A face shield is also required any time there is a risk of explosion or highly exothermic reaction. All manipulations of pyrophoric chemicals which pose this risk must occur in a fume hood with the sash in the lowest or most protective position. Portable shields (i.e., blast shields), which provide protection to all laboratory occupants, shall also be used as necessary.

- Gloves must be worn when handling pyrophoric chemicals. Nitrile gloves may be adequate for handling small quantities of most of these in general laboratory settings. However, nitrile gloves are combustible, and heavy chemical-resistant gloves or Nomex and related aramid fiber gloves may be appropriate for working with large quantities.
- Appropriate shoes that cover the entire foot (closed toe, closed heel, no holes in the top) must be worn at all times. For optimal protection, we strongly recommend the use of leather shoes.

7.0 Engineering Controls

The following is the set of engineering controls required when handling air/water reactive chemicals:

- **Fire Extinguishers**. Laboratory personnel working with reactive materials must have the proper equipment and the emergency phone number readily available for any emergencies, prior to starting research activities. Acceptable extinguishing media include soda ash (lime) or dry sand to respond to fires. DO NOT use water to attempt to extinguish a pyrophoric/water-reactive chemical fire as it can actually enhance the combustion of some of these materials, e.g. metal compounds. A small beaker of dry sand or soda ash (lime) in the work area is useful to extinguish any small fire that occurs at the syringe tip and to receive any last drops of reagent from the syringe. Review the SDS for the proper fire extinguisher to use with the given material, or contact Fire Marshal's Office (3-5858) for assistance.
- **Eye wash and safety shower** shall be within 10 seconds walking time from the location of a hazard (approximately 55 feet). Ensure that each of these safety devices has been certified with appropriate date stamp. Bottle type eyewash stations are not acceptable.
- **Fume Hood**: Verify that the fume hood has been checked within the last 12 months. Many pyrophoric chemicals release noxious or flammable gases, and some air/water reactive chemicals are stored under kerosene. These materials must always be handled in a laboratory fume hood. Therefore the use of a fume hood (or glove box) is required to prevent the release of flammable vapors into the lab.
- **Inert atmosphere glove boxes** are an excellent device for the safe handling of reactive materials. Glove boxes used for this purpose shall be in good working order and the moisture and oxygen levels of the atmosphere shall be confirmed prior to introduction of reactive compounds into the box. Anyone working with glove box must be trained on the standard operating procedures for the box and review these SOPs with their PI prior to beginning work.

8.0 Administrative Controls

- Only order and store the quantities of pyrophoric/water-reactive chemicals that are needed. Choose less hazardous reagents when possible.

- All Laboratory Personnel who directly use pyrophoric/water-reactive chemicals must be hands-on trained by the PI or knowledgeable designee before using pyrophoric/water-reactive chemicals and must have undergone all general safety training requirements as well, must be documented. When under training, they shall be supervised until they are competent to use pyrophoric/water-reactive chemicals independently.
- All Laboratory Personnel who work in the lab with pyrophoric/water-reactive chemicals, but not directly use pyrophoric/water-reactive chemicals must be in-person trained on these specific procedures by the PI or knowledgeable designee before start working in the laboratory and must have undergone all general safety training requirements as well, and must be documented.
- All users must review SDS documents and standard operating procedures before using pyrophoric/water-reactive chemicals.
- At least one **other** person must be present in the laboratory when pyrophoric/water-reactive chemicals are in use.

8.1 **Special Handling and Storage Requirements**

When handling pyrophoric/water-reactive chemicals, **no one shall work alone or during off hours**, when there are few people around to help.

- Use and store minimal amounts of pyrophoric/water-reactive chemicals. Do not store pyrophoric/water-reactive chemicals with other flammable materials or in a flammable liquids storage cabinet. Containers carrying pyrophoric/water-reactive chemicals must be clearly labeled with the correct chemical name and hazard warning at a minimum.
- Pyrophoric/water-reactive chemicals shall be handled in systems or enclosures (glove boxes) that prevent the chemicals from igniting when a dry or an inert atmosphere is required by the manufacturer or the safety data sheet.
- Pyrophoric/water-reactive shall be handled only by those with experience in their hazards and properties or under close, direct supervision by those with experience in their hazards and properties. Work with pyrophoric/water-reactive chemicals during transfer or cleanup operations requires the use of the buddy system.
- Personal Protective Equipment shall be worn as required in Section 6.0.
- Pyrophoric liquids dispensed in a chemical fume hood shall be from sure-seal-type bottles with syringes or double-tipped needles in accordance with the manufacturer's recommendation.
- Open dispensing of pyrophoric liquids shall be done inside of an inert atmosphere glove box. Pyrophoric solids shall be handled/dispensed inside of an inert atmosphere glove box. Water reactive solids that are not protected by mineral oil or solvents shall be handled/dispensed inside of an inert atmosphere glove box.
- Residual moisture and contaminates shall be cleaned from reaction vessels, glassware, needles, and other lab equipment that will be exposed to pyrophoric reagents and water reactive materials. Equipment shall be purged with a high-purity dry inert gas prior to use.
- The void space at the top of containers of pyrophoric reagents shall be backfilled with a high-purity dry inert gas as the reagent is removed.

- Store pyrophoric/water-reactive chemicals as recommended in the SDS or product guidance. Inert gas-filled desiccators or glove boxes are suitable storage locations for most materials.
- Pyrophoric/water-reactive materials in glove boxes shall be sealed in airtight containers when the chemicals are not in use.
- If pyrophoric/water-reactive chemicals are received in a specially designed shipping, storage, or dispensing container (such as the Aldrich Sure/Seal packaging system) ensure that the integrity of that container is maintained.
- Ensure that a sufficient protective solvent, oil, kerosene, or inert gas remains in the container while the material is stored.
- **Never** return any excess chemical to the original container. Material must be used up as part of the experimental procedure or quenched using an appropriate technique as indicated in laboratory-specific SOP. Excess shall be quenched using an appropriate safe technique.
- Do not store pyrophoric/water-reactive chemicals for longer than necessary. Use chemicals as quickly as possible.

8.2 Disposal of pyrophoric and water-reactive chemicals

- Never leave a container with a residue of a pyrophoric/water-reactive chemical open to the atmosphere.
- Any unused or unwanted pyrophoric/water reactive chemicals must be destroyed by transferring the materials to an appropriate reaction flask for hydrolysis and/or neutralization with adequate cooling. If you have large quantities of unreacted pyrophoric reagent material, contact EHLS at 3-5858 for guidance on disposal options.
- The empty container shall be rinsed three times with an inert dry compatible solvent; this rinse solvent must also be neutralized or hydrolyzed as described below in the lab-specific procedures. The rinse solvent must be added to and removed from the container under an inert atmosphere.
- All materials (disposable gloves, wipers, bench paper, etc.) that are contaminated with pyrophoric/water-reactive chemicals must be disposed of as hazardous waste. Proper and complete hazardous waste labelling of containers is vital.
- The contaminated needles, spatulas, wipes, and tools that have been in contact with pyrophoric/water-reactive chemicals shall be stored in an inert atmosphere or shall be neutralized in accordance with the manufacturer's written instructions and the laboratory-specific instructions.
- Alert EHLS for any wastes contaminated by pyrophoric/water-reactive chemicals by adding in comments during the electronic submission process.
- EHLS cannot remove materials from the lab until they have been appropriately stabilized/quenched and deemed safe for transport.

9.0 **Emergency Procedures**

- DO NOT use water to attempt to extinguish a reactive material fire as it can actually enhance the combustion of some reactive materials, e.g. metal compounds.
- Do not use combustible materials (paper towels) to clean up a spill, as these may increase the risk of igniting the reactive compound. Soda ash (powdered lime) or dry sand shall be used to completely smother and cover any small spill that occurs.
- A container of soda ash (powdered lime) or dry sand shall be kept within arm's length when working with a reactive material.
- If anyone is exposed, or on fire, wash with copious amounts of water, except if metal compounds are involved, which can react violently with water. In the case of a metal fire, smothering the fire is a better course of action.
- Call 9-1-1 from campus phone or 713-743-3333 for emergency assistance and for assistance with all fires, even if extinguished.
- Pyrophoric gas releases and associated fires, must be extinguished by remotely stopping the gas flow. Never attempt to put out a gas fire if the gas is flowing.

10.0 Standard Operating Procedures Template for Pyrophoric/Water-reactive Chemicals

UNIVERSITY of HOUSTON
ENVIRONMENTAL HEALTH & LIFE SAFETY

Joe Tremont
Director for Environmental Health and Safety
Phone: 713-743-5861
Fax: 713-743-8035

Chemical Name: Pyrophoric/Water-Reactive Chemicals

STANDARD OPERATINGPROCEDURES

This is an SOP template and is not complete until: 1) lab specific information is entered into the box below 2) lab specific protocol/procedure is added to the protocol/procedure section and 3) SOP has been signed and dated by the PI and relevant lab personnel.

According to the Safety Data Sheet (SDS) for Pyrophoric/Water-Reactive Chemicals special precautions must be taken when working with this chemical. This operating procedure briefly describes the use of the equipment and supplies maintained at the facility, procedures that must be followed, and the responsibilities of personnel when working in these facilities. Amend SOP to reflect changes in procedure, equipment, etc. Do not conduct experiments, even pilot studies, which are not described in this approved SOP. It is essential that all personnel follow the appropriate procedures outlined in this SOP. **Please provide the SDS associated with this chemical.**

PI Acknowledgement

Name:	
Dept:	
PSID:	
Date:	

	1. PI Responsibilities (Please initial before each responsibility below.)	
	The Principal Investigator is responsible for training employees using the chemical. The training shall include a discussion of the known and potential hazards and an explanation of the relevant policies, techniques and procedures including the proper use of personal protective equipment and containment equipment.	
	Employees shall be trained initially and then annually thereafter. Their knowledge, competence and practices shall be evaluated and documented.	
	Implement a safety program and include this information in the chemical hygiene plan.	
	Limit access to authorized users.	
	Minimize the possibility of direct skin or eye contact with the drug or inadvertent ingestion/inhalation.	

	Transportation of the chemical within the facility shall be performed using a sealed non-breakable secondary container.
	Develop Standard Operating Procedures (SOP) for delivery and storage of the chemical. The SOP shall have a contingency plan for broken or leaking bottles.
	Properly label containers and any secondary containers of the chemical.
	Provide SDS via email to ehs@uh.edu

2. Chemical Information

a. List the chemical names and CAS numbers of pyrophorics/water-reactive chemicals in your lab

Chemical Names	CAS Numbers

3. Hazard Identification

Indicate why this is a PHS (there may be more than one category):

☐ High Acute Toxicity	☐ Carcinogen	☐ Reproductive toxin
☐ Air Reactive/Pyrophoric material	☐ Water reactive	☐ Explosive/unstable
☐ Other (specify)	☐	

Indicate other hazards:

☐ Flammable	☐ Corrosive	☐ Oxidizer
☐ Reactive	☐ Temperature sensitive	☐ Sensitizer
☐ Other (specify)		

4. Storage

Please review Section 5.0 and 8.1 of UH Guideline for Pyrophoric/Water-reactive Chemicals.

Any incompatible materials or conditions:

More lab-specific info:

5. Engineering Controls

Please review Section 7.0 of UH Guideline for Pyrophoric/Water-reactive Chemicals.

List the location of fume hood(s), glove boxes, safety shower and eyewashes:

Type	Location (building and room number)
Fume hood (s)	
glove boxes if applicable	
Safety shower	
eyewashes	

6. Work Practice Controls

Please review Section 8.0 and 8.1 of UH Guideline for Pyrophoric/Water-reactive Chemicals.

When handling pyrophoric/water-reactive chemicals, no one shall work alone or during off hours, when there are few people around to help.

Designated Area:
(All PHS material must be stored and used in a designed work area. (You may designate your entire lab.) Indicate the designated for PHS use and how it will be posted).

7. Personal Protective Equipment (PPE)

Please review Section 6.0 of UH Guideline for Pyrophoric/Water-reactive Chemicals.

Personal protective equipment is especially important.
Handle with _____ **gloves (indicate the glove material)**. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.
Wear ANSI approved safety glasses or goggles when handling the chemical.
Lab coats shall be worn. These laboratory coats must be appropriately sized for the individual and be buttoned to their full length. Laboratory coat sleeves must be of a sufficient length to prevent skin exposure while wearing gloves. Full length pants and close-toed shoes must be worn at all times by all individuals that are occupying the laboratory area. The area of skin between the shoe and ankle shall not be exposed. **A flame resistant lab coat must be worn when working with pyrophoric chemicals.**

More lab-specific info:

8. Waste Disposal

Please review Section 8.2 of UH Guideline for Pyrophoric/Water-reactive Chemicals.

All chemical waste must be disposed of following your laboratory-specific chemical hygiene plan and the requirements of UH Hazardous Waste Manual.

Indicate details of disposal for the PHS and any subsequent materials where it is present (such as glassware, sample containers, etc.):

9. Exposures (e.g. ingestion, skin contact, inhalation, etc.) and Spills

Please review Section 9.0 of UH Guideline for Pyrophoric/Water-reactive Chemicals.

More lab-specific info:

10. Lab-specific Protocol/Procedure (Below is an example, please add lab specific Protocol/Procedure here or attach additional pages as necessary)

For example: Please clearly indicate how to quench excess materials.

11. EHLS Policy Requires

EHLS policy requires that all chemical hazards must be clearly identified. If you have any questions regarding risk assessment and SOP development, contact the EHLS office 713-743-5858 or ehs@uh.edu

This plan must be supplemented with the University of Houston Chemical Hygiene Plan and must include special practices when working with a particular chemical and the SDS must be accessible.

PI Acknowledgement

By signing this form the individual certifies that the information provided is true and correct to the best of their knowledge.

Name:		E-Mail:	
Signature:		Date:	
Office Phone:		Cell Phone:	

Trainer Acknowledgement

"I acknowledge that I have provided below training(s) to the users listed in 'Trained Laboratory Personnel'."

(check all the apply)

☐ **Review** the UH Chemical Hygiene Plan

☐ **Review** the SDS for the pyrophoric/water-reactive chemicals, *if available*

☐ **Review** the SDS for other chemicals involved in the experiment/process

☐ **Review** this SOP

☐ **Hands-on trainings** on pyrophoric/water-reactive chemicals (This is required for Laboratory Personnel who directly use pyrophoric/water-reactive chemicals)

Name:		E-Mail:	
Signature:		Date:	

Trained Laboratory Personnel

a. For Laboratory Personnel who directly use pyrophoric/water-reactive chemicals

Please note Lab Personnel in this category must be given hands-on training for procedures/experiments involving pyrophoric/water-reactive materials before beginning work. This document must be supplemented with UH Chemical Hygiene Plan and must include special practices when working with a particular chemical and the SDS must be accessible.

Hands-on training on these specific procedures must be performed by the PI or knowledgeable designee for all personnel working with pyrophoric materials, and must be documented (topics covered, date, employee names and signatures). All personnel shall read and fully adhere to the laboratory-SOP for any pyrophoric/water-reactive chemicals, and shall document that they have read it by signing and dating the SOP.

"I have read and understand this guideline and laboratory-specific standard operating procedures . I agree to fully adhere to its requirements. By signing below, I acknowledge that I have received hands-on training for use of pyrophoric/water-reactive chemicals."

Last	First	PSID	Email	Signature	Date

b. For Laboratory Personnel who work in the lab with pyrophoric/water-reactive chemicals, but not directly use pyrophoric/water-reactive chemicals

Lab Personnel in this category must be given in-person training for procedures/experiments involving pyrophoric/water-reactive before beginning work. This document must be supplemented with UH Chemical Hygiene Plan and must include special practices when working with a particular chemical and the SDS must be accessible.

In-person training on these specific procedures must be performed by the PI or knowledgeable designee for all personnel working with pyrophoric/water-reactive materials, and must be documented (topics covered, date, employee names and signatures). All personnel shall read and fully adhere to the laboratory-specific SOP for any pyrophoric/water-reactive, and shall document that they have read it by signing and dating the SOP.

"I have read and understand this guideline and laboratory-specific procedures/protocols indicated in Section 10. I agree to fully adhere to its requirements. By signing below, I acknowledge that I have received in-person training for use of pyrophoric/water-reactive chemicals."

Last	First	PSID	Email	Signature	Date

*This document, including the signature page with signatures by all involved personnel shall be maintained by the Principal Investigator or Designee, and be submitted to EHLS either electronically via the ehs@uh.edu or hard copy upon request.

Appendix 9. UH Guideline for Chemotherapy and Other Hazardous Drugs Safe Use

UNIVERSITY of HOUSTON

UH Guideline for Chemotherapy and Other Hazardous Drugs Usage

Prepared by:

Environmental Health and Life Safety (EHLS)

http://www.uh.edu/ehls/

Revision June 2018

EHLS Phone: 713-743-5858

Table of Contents

I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) has defined hazardous drugs as those that exhibit one or more of the following six characteristics in humans or animals:

- Carcinogenicity
- Teratogenicity or other developmental toxicity
- Reproductive toxicity
- Organ toxicity at low doses
- Genotoxicity
- Structure and toxicity profiles of new drugs that mimic existing drugs determined hazardous by the above criteria

NIOSH recommends that all hazardous drugs be handled safely and has published guidelines in their *2004 NIOSH Alert: Preventing Occupational Exposures to Antineoplastic and Other hazardous Drugs in Health Care Settings*. This applies primarily to workers in health care settings, but also applies to those who work with hazardous drugs in research laboratories, which is the focus in this document. Hazardous drugs include those used for cancer chemotherapy, antiviral drugs, hormones, some bioengineered drugs and other miscellaneous drugs. See *NIOSH sample listing of major hazardous drugs (2014, or most recent edition), the majority of which are chemotherapy drugs.*

The nature of chemotherapy drugs* (cancer chemotherapeutic drugs, antineoplastic agents or cytotoxic drugs) makes them harmful to healthy cells and tissues as well as cancerous cells. For cancer patients with a life-threatening disease, treatment with these agents can be beneficial. However, for researchers and workers who are exposed to chemotherapy drugs as part of their work, precautions must be taken to eliminate or reduce the potential for exposure as much as possible. Chronic effects that have been identified in patients given these drugs include cancer, infertility, miscarriage, birth defects, damage to the liver and kidney, bone marrow, the lungs and heart, and hearing impairment. Acute effects may include headache, nausea, irritation of eyes, skin and mucous membranes, allergic reactions and skin rash. Employees inadvertently exposed may have similar effects. The risk varies with the specific drug and its concentration and with the frequency and duration of exposure. Other hazardous drugs may produce comparable effects.

In a research laboratory setting, researchers may be exposed to chemotherapy or other hazardous drugs by inhalation of agent powder or aerosol produced during preparation, administration or cleanup activities. Skin exposure with agents may occur during preparation or administration of the agent, contact with contaminated work surfaces, clothing and equipment, or by needle-stick incidents. Exposure risks can be greatly reduced by (1) making sure that engineering controls such as fume hoods, exhausted biological safety cabinets (BSC) and other exhausted enclosures are used and (2) using proper procedures and protective equipment for handling chemotherapy and other hazardous drugs.

Principal Investigators (PIs) are required to assess the exposure hazards of their work with chemotherapy and other hazardous drugs to determine the appropriate precautions and controls to be taken. The assessment includes, at a minimum, the types, forms and volumes of hazardous drugs used, the procedures performed, engineering controls, personal protective equipment (PPE),

decontamination and cleaning, spill response, waste handling and emergency procedures in case of possible exposure or other emergency. EHLS will assist PIs as needed in their exposure hazard assessment. PIs must provide lab personnel laboratory-specific chemical training for the specific agents they are working with. The hazardous chemical training must include but is not limited to the health and physical hazards of the agents, signs and symptoms associated with exposure, appropriate work practices, PPE, work practices and emergency procedures in case of spill or possible exposure. Review of the safety data sheet/material safety data sheet (SDS/MSDS) is required and practice with less hazardous materials is recommended prior to work with the agents.

* “chemotherapy drugs” are also referred to in this document as “antineoplastic agents”, “chemotherapeutic drugs”, “chemo” and “agents”

II. LABORATORY PLANNING AND PREPARATION FOR USE

1. Develop a written laboratory-specific SOP specific to the chemotherapy or hazardous drug being used.

2. Provide and document hazardous chemical training and specific agent SOP training to personnel working with chemotherapy/hazardous drugs and any others authorized or required to be in the laboratory or shared space during work with the agent(s). A sample training documentation form is on the last page of the template SOP.

3. Ensure the agent SDS/MSDS is available to staff at all times.

4. Enter agent into Chemical Inventory List.

5. Determine any special procedures and precautions needed for the agents used. This may include precautions for work with volatile chemotherapy drugs (details given in III. ENGINEERING CONTROLS section).

6. Select appropriate chemotherapy gloves that will be used with the specific agents. Determine any special procedures and precautions needed if working with agents that may readily permeate chemotherapy gloves (details given in IV. PERSONAL PROTECTIVE EQUIPMENT section).

7. Designate a laboratory, work space and certified exhausted BSC, fume hood, glove box or other approved containment for agent work. The laboratory facilities required may vary based on the level of hazard posed by the specific agent and the procedures being performed.

8. Store chemotherapy and other hazardous drugs in an area labeled chemotherapeutic/hazardous drugs.

9. Purchase the smallest amount of agent feasible for work, or purchase the agent in the concentration for use. If possible, do not work with chemotherapy/hazardous drugs in solid or powder form. If it is necessary to purchase it in powder or solid form, purchase pre-diluted or pre-weighed agent in the least quantity needed to perform work.

10. Ensure supplies are available for agent waste handling and disposal, and for routine cleaning of surfaces.

11. Ensure supplies for spill cleanup are appropriate for the specific agent, maintained in a clearly marked spill cleanup kit and readily available in the laboratory.

III. ENGINEERING CONTROLS

1. Prepare agents in an exhausted BSC, fume hood, glove box or other approved containment that does not exhaust into the room. Do not use laminar flow cabinets or hoods for agent work. Consider the properties of the specific agent and procedures when selecting a containment device. Working with intact tablets or capsules is not required to be done in exhausted containment. However, if crushing tablets, perform work in exhausted containment.

2. Do not use a ventilated cabinet that recirculates air inside the cabinet when working with volatile agents. Most agents are not volatile, but some are. The following agents have been reported in publications to be volatile under certain conditions:

Carmustine	Ifosfamide
Cyclophosphamide	Mechlorethamine (Mustargen)
Doxorubicin	ThioTEPA

IV. PERSONAL PROTECTIVE EQUIPMENT (PPE)

1. Wear disposable, powder-free chemotherapy gloves that are approved by the Food and Drug Administration (FDA) and have been tested for use with chemotherapy drugs. These gloves are also recommended for handling other hazardous drugs. Always use powder-free gloves. Glove powders contaminated with chemotherapy drugs can become airborne and may be subsequently inhaled. Also, powder residue will attach to supplies, work surfaces and the skin.

2. Wear two pairs of gloves for most activities working with hazardous drugs. A single pair of gloves should provide adequate protection when working with intact tablets or capsules.

3. When double gloving, place one glove under the gown cuff and one over. Change the outer glove immediately if contaminated. Change both gloves if an outer glove is torn, punctured, or overtly contaminated with the agent (as in a spill) and every hour during preparation. If there is a risk of permeation, change gloves every 30 minutes or less.

4. Other glove notes:

- Gloves must be protective from any solvents used, in addition to the chemo/hazardous drug.
- The lab should have several sizes of gloves available for best fit – not too tight to impede movement and not too loose to decrease dexterity.

5. Wear a protective gown or equivalent that is lint-free, non-permeable with a solid front, long sleeves, and tight-fitting elastic or knit cuffs. Wear long pants or long skirt, and fully closed shoes.

6. Wear safety glasses with side shields or goggles.

7. Wear face protection, such as a face shield, when splash/splatter is possible.

8. Disposal of disposable PPE, is described in Section IX. AGENT WASTE COLLECTION AND DISPOSAL.

9. Respiratory protection may be required if an airborne hazard is present when work is done outside of approved containment or when cleaning up a spill. Surgical masks or dust masks do not provide adequate protection. For information see EHLS Respiratory Protection Program or contact the EHLS occupational specialist at 713-743-5858.

V. SAFE USE PRACTICES (reconstitution, dilution)

1. All agent preparation must be performed in a chemical fume hood, glove box, exhausted BSC or other approved containment.

2. Perform preparations over plastic backed absorbent pads. Dispose of pads after completion of tasks or immediately upon contamination as chemotherapy waste.

3. Transport agents only in labeled, leak/spill-proof, non-breakable secondary containment.

4. Decontaminate surfaces by cleaning with detergent and water followed by thorough rinsing. The use of detergent is recommended because there is no single accepted method of chemical deactivation for all agents involved. 70% isopropyl alcohol may be used with the cleaner if the contamination is soluble only in alcohol.

5. Clean work surfaces before and after each activity and at the end of the work shift. Establish periodic cleaning routines for all work surfaces and equipment that may become contaminated.

6. Decontaminate the chemical fume hood, BSC or glove box, and other work surfaces before and after each task and at the end of the work shift.

7. Decontaminate containers before they are removed from the fume hood, BSC, or glove box. Also decontaminate the exterior of the closed primary container and place it in a clean secondary container.

8. Dispose of unused excess chemotherapy and hazardous drug in the proper waste container (details given in IX. AGENT WASTE COLLECTION AND DISPOSAL section). Submit request to EHLS for waste pickup.

9. Place all visibly contaminated disposable items, such as gloves, paper towels and absorbent pads, in a plastic bag while in the fume hood, BSC or other containment and then in the proper waste container (details given in IX. AGENT WASTE COLLECTION AND DISPOSAL section).

10. When work completed, remove gloves and wash hands with soap and water.

VI. PRECAUTIONS FOR AGENT ADMINISTRATION

1. Wear double gloves for all procedures involving administration of chemotherapy/hazardous drugs.

2. Change gloves every 30 to 60 minutes or after each use, or immediately when torn, punctured, or contaminated.

3. Wear protective gown with solid front. Change gowns every two to three hours or when contaminated.

4. Utilize safe sharps procedures. Dispose of sharps in a yellow sharps container specific for chemotherapy or other hazardous drugs. The sharps container must be in the immediate vicinity of work and labeled as holding chemotherapy/hazardous drug items.

5. In animal studies, restrain or anesthetize animals when possible before injecting chemotherapy/hazardous drugs.

VII. AGENT SPILL CLEANUP

Chemotherapy and other hazardous drug spills must be cleaned up as soon as possible **by properly protected and trained personnel**. All other persons must leave the area. Spill response procedures must be developed based on the hazardous agent present and potential spill or release conditions. Clean up spills using contents of the chemotherapy/hazardous drug spill kit. **Do not attempt to clean up any spill if not trained or comfortable. Evacuate the area and call 911 from campus line or UHPD 713-743-3333 for help. If the spill is out of control or if a person is injured, exposed or suspected of being exposed, call 911 from campus line or UHPD 713-743-3333. Follow Section VIII. ACUTE EXPOSURE procedures below.**

Spills inside a BSC, fume hood, glove box or approved containment

1. Personnel must wear a lab coat, safety goggles, two pairs of disposable chemotherapy gloves (or one pair of non-disposable nitrile or butyl gloves (minimum 10 mil thickness) or Silver Shield gloves), when cleaning up spills.

2. Liquids: Wipe up spilled liquids with absorbent pads.

3. Powders: Gently cover powder spill with wetted paper towels or absorbent pads to avoid raising dust and then wipe up.

4. Clean the spill area thoroughly with detergent solution followed by clean water.

5. If spill is extensive within the containment, clean all interior surfaces after completion of the spill cleanup.

6. Double bag all waste in plastic bags labeled with the contents. Submit request to EHLS for waste pickup.

Small Spills (less than 5 ml) outside of containment

1. Personnel must wear a lab coat with solid front, safety goggles, shoe covers as needed and two pairs of disposable chemotherapy gloves (or one pair of non-disposable nitrile or butyl gloves (minimum 10 mil thickness) or Silver Shield gloves), when cleaning up spills.

2. Wear an N95 or equivalent respirator for either powder or liquid spills where airborne powder or aerosol is or has been generated. Spills of volatile agents require the use of an appropriate combination particulate/chemical cartridge-type respirator. Most chemotherapy drugs are not volatile, but some are. Assess the volatility of the agent. Please contact the EHLS Respiratory Protection Program administrator to discuss respiratory protection or to enroll in the program. Program enrollment includes medical evaluation, training and fit testing for an appropriate respirator. For information see EHLS Respiratory Protection Program or call EHLS at 713-743-5858.

3. Liquids: Wipe up spilled liquids with absorbent pads.

4. Powders: Gently cover powder spill with wetted paper towels or absorbent pads to avoid raising dust and then wipe up.

5. Clean the spill area thoroughly with detergent solution followed by clean water.

6. Double bag all waste in plastic bags labeled with the contents. Submit request to EHLS for waste pickup.

Large spills (greater than 5 ml) outside of containment

1. Evacuate all personnel from the laboratory and restrict access.

2. As soon as possible report the spill by notifying EHLS (during business hours (M-F/8-5) 713-743-5858, outside business hours 911 from campus line or UHPD 713-743-3333); tell them that a spill has occurred, and that you need help managing the spill. Notify supervisor.

3. Be prepared to provide the following information:

- Name and phone number of knowledgeable person that can be contacted
- Name of agent spilled, concentration and amount spilled, liquid or solid type spill
- Number of injured, if any (refer below to Section VIII, Acute Exposure)
- Location of spill

4. **Only if staff are trained, have the proper PPE and are comfortable with cleaning up the spill, they may proceed to clean it up.** Personnel must wear a lab coat with solid front, safety goggles, shoe covers as needed, and two pairs of disposable chemotherapy gloves (or one pair of non-disposable nitrile or butyl gloves (minimum 10 mil thickness) or Silver Shield gloves), when cleaning up spills.

5. Wear an N95 or equivalent respirator when cleaning large spills. Spills of volatile agents require the use of an appropriate combination particulate/chemical cartridge-type respirator. Most chemotherapy

agents are not volatile, but some are. Assess the volatility of the agent. Please contact the EHLS to discuss respiratory protection or to enroll in the program. Program enrollment includes medical evaluation, training and fit testing for an appropriate respirator. For information call EHLS at 713-743-5858.

6. Liquids: Wipe up spilled liquids with absorbent pads.

7. Powders: Gently cover powder spill with wetted paper towels or absorbent pads to avoid raising dust and then wipe up.

8. Clean the spill area thoroughly with detergent solution followed by clean water.

9. Double bag all waste in plastic bags labeled with the contents. Submit request to EHLS for waste pickup.

VIII. ACUTE EXPOSURE

1. Provide First Aid Immediately

- Inhalation: Move out of contaminated area. Get medical help.

- Sharps injury (needlestick and subcutaneous exposure): Scrub exposed area thoroughly for 15 minutes using warm water and sudsing soap.

- Skin exposure Use the nearest safety shower for 15 minutes. Stay under the shower and remove clothing. Use a clean lab coat or spare clothing for cover-up.

- Eye exposure Use the eye wash for 15 minutes while holding eyelids open.

IX. AGENT WASTE COLLECTION AND DISPOSAL

Manage chemotherapy and hazardous drug waste separately from other waste streams such as biohazardous waste. Never autoclave chemotherapy/hazardous drug waste since it can produce hazardous chemical vapors or aerosols, and autoclaving conditions may not be sufficient to deactivate chemotherapy/hazardous drug waste.

Environmental Health and Life Safety (EHLS) is tasked with the disposal of biological, chemical and other regulated wastes generated on campus. Procedures for Waste Disposal from the Animal Use Areas please see Appendix N on Regulated Waste Manual (new Hazardous Waste Manual).

Appendix 10. UH Guideline for Peroxide Forming Materials

UH Guideline for Peroxide Forming Materials

Introduction

Peroxide-forming materials are a class of chemical compounds that have the ability to form shock-sensitive explosive peroxide crystals. Many of the organic solvents commonly used in laboratories have the potential to form explosive peroxide crystals. Since specific chemical reactions and research protocols may require use of peroxide forming substances, it's imperative that each lab's inventory of peroxide-forming materials is managed properly. Peroxide forming materials must be dated when received and opened. They also must be disposed of through EHLS within one year from the date of opening or by the manufacturer's expiration date, whichever occurs first. This particular guideline was created by Environmental Health and Life Safety with the goal of complying with 29 CFR 1910.1450 (e)(3)(i) and educating the campus community in the safe use of peroxide forming materials.

Purpose and Scope

This guideline present information on how to handle and store peroxide forming materials safely. All UH Laboratory Personnel who work in labs containing peroxide forming materials must familiarize themselves with this document. A copy of the signature page, the last page of this document, must be kept by the PI and Designee acknowledging Laboratory Personnel have read this document and are aware of the unique dangers and precautions that must be taken when handling these substances.

Overview of Hazards

A wide variety of organic compounds spontaneously form peroxides by a free radical reaction of the hydrocarbon with molecular oxygen. Under normal storage conditions the materials listed in this document have the potential to generate and accumulate peroxide crystal formations, which may violently detonate when subjected to thermal or mechanical shock. Peroxide-forming chemicals react with oxygen – even at low concentrations – to form peroxy compounds. The risk associated with peroxide formation increases if the peroxide crystallizes or becomes concentrated by evaporation or distillation. Factors that affect rate of peroxide formation include exposure to air, light and heat, moisture, and contamination from metals.

Peroxides tend to form in materials as a function of age. Therefore, it is imperative that researchers are keenly aware of the age of their peroxide-forming chemicals. Researchers must date each container upon arrival in the laboratory. Containers must be dated again when opened for the first time. An appropriate expiration date based on what type of peroxide susceptible

chemical the item is should also be on the label. Time Limited Material labels are available from EHLS at the link below.

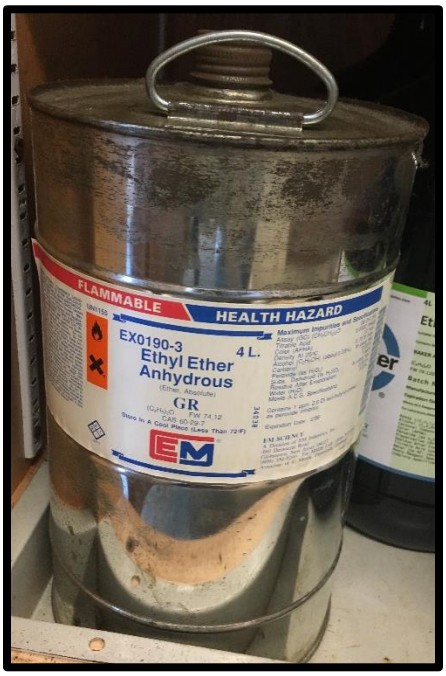
https://www.uh.edu/ehls/labs/labels/Time-limited-primary-container.pdf

Many methods can be used to stabilize or inhibit the peroxidation of susceptible chemicals. If it does not interfere with the use of the chemical and, if available, peroxide-forming chemicals should be ordered with inhibitor added and peroxide scavengers (inhibitors) should be added in small quantities to items that have been redistilled.

Manufacturers may add an inhibitor to peroxide forming chemicals to counter peroxide formation. For many peroxide-forming solvents, butylated hydroxy toluene (BHT) is commonly added. BHT 'scavenges' oxygen in the solvent and prevents it from reacting with the solvent to form peroxides. Over time, BHT or other inhibitor in the solvent can become exhausted allowing peroxides to form. Distilling the solvent can completely remove the BHT and make the solvent immediately susceptible to peroxide formation. Peroxide crystals may form on the container plug or the threads of the lid and detonate when the lid is twisted. Do not open a liquid organic peroxide or peroxide-forming chemical if crystals or a precipitate are present.

Ideally, purchases of peroxide-forming chemicals should be restricted to ensure that these chemicals are completely used up completely before they can form peroxide crystals. This requires careful experiment planning. Researchers should purchase no more material than is needed to complete an experiment within the chemical's safe shelf life.

Figure 1 – Ethyl Ether Anhydrous



Older containers of peroxide-forming chemicals, or containers of unknown age or history, must be handled very carefully and should never be opened by researchers. Any peroxide-forming chemical with visible discoloration, crystallization or liquid stratification should be treated as potentially explosive. Older steel containers that have visible rust may also be extremely dangerous. If any of these conditions are observed on a peroxide-forming chemical container, or if the origin and age of the container are unknown, do not attempt to move or open the container. Contact EHLS at ehs@uh.edu or 713-743-5858 to have the container inspected and, if necessary, disposed of properly.

Figure 1 - Can of Ethyl Ether Anhydrous found 23 years after manufacturer's expiration date with extensive rust on the container as well as the cap. Even though stabilized with BHT, due to its age and condition, this container had to be disposed of by a bomb squad at a cost of greater than $2,500 to UH.

Classes of Peroxide Forming Materials

Organic azo compounds and peroxides are among the most hazardous substances handled in the chemical laboratory but are also common reagents that often are used as free radical sources and oxidants. They are generally low-power explosives that are sensitive to shock, sparks, or other accidental ignition. They are far more shock sensitive than most primary explosives such as TNT. Inventories of these chemicals should be limited and subject to routine inspection. Many require refrigerated storage. Liquids or solutions of these compounds should not be cooled to the point at which the material freezes or crystallizes from solution, however, because this significantly increases the risk of explosion. Refrigerators and freezers storing such compounds should have a backup power supply in the event of electricity loss. Users should be familiar with the hazards of these materials and trained in their proper handling.

Certain common laboratory chemicals form peroxides on exposure to oxygen in air (see tables below). Over time, some chemicals continue to build peroxides to potentially dangerous levels, whereas others accumulate a relatively low equilibrium concentration of peroxide, which becomes dangerous only after being concentrated by evaporation or distillation. The peroxide becomes concentrated because it is less volatile than the parent chemical. A related class of compounds includes inhibitor-free monomers prone to free radical poly-merization that on exposure to air can form peroxides or other free radical sources capable of initiating violent polymerization. Note that care must be taken when storing and using these monomers - most of the inhibitors used to stabilize these compounds require the presence of oxygen to function properly, as described below. Always refer to the SDS and supplier instructions for proper use and storage of polymerizable monomers.

Essentially all compounds containing C—H bonds pose the risk of peroxide formation if contaminated with various radical initiators, photosensitizers, or catalysts. For instance, secondary alcohols such as isopropanol form peroxides when exposed to normal fluorescent lighting and contaminated with photosensitizers, such as benzophenone. Acetaldehyde, under normal conditions, autoxidizes to form acetic acid. Although this autoxidation proceeds through a peroxy acid intermediate, the steady-state concentrations of that intermediate are extremely low and pose no hazard. However, in the presence of catalysts (Co^{2+}) and under the proper conditions of ultraviolet light, temperature, and oxygen concentration, high concentrations of an explosive peroxide can be formed. The chemicals described in the table below represent only those materials that form peroxides in the absence of such contaminants or otherwise atypical circumstances.

Class A: Chemicals that form explosive levels of peroxides without concentration

Butadiene
Chlorobutadiene (chloroprene)
Divinyl acetylene
Isopropyl ether
Potassium amide
Potassium metal
Sodium amide (sodamide)
Tetrafluoroethylene
Vinylidene chloride

Class B: These chemicals are a peroxide hazard on concentration (distillation/evaporation). A test for peroxide should be performed if concentration is intended or suspected.

Acetal
Cumene
Cyclohexene
Cyclooctene
Cyclopentene
Diaacetylene
Dicyclopentadiene
Diethylene glycol dimethyl ether (diglyme)
Diethyl ether
Dioxane (*p*-dioxane)
Ethylene glycol dimethyl ether (glyme)
Furan
Methyl acetylene
Methyl cyclopentane
Methyl-isobutyl ketone
Tetrahydrofuran
Tetrahydronaphthalene
Vinyl ethers

Class C: Unsaturated monomers that may autopolymerize as a result of peroxide accumulation if inhibitors have been removed or are depleted.

Acrylic acid
Butadiene
Chlorotrifluoroethylene
Ethyl acrylate
Methyl methacrylate
Styrene
Vinyl acetate
Vinyl chloride
Vinyl pyridine

Sources: Prudent Practices in the Laboratory, NAP 2011.

Evaluating & Testing Peroxide Forming Materials

Upon discovering potential peroxide forming materials, do not remove from the storage location until a thorough evaluation of the material has been completed using the attached evaluation. After the evaluation, review all information to make a decision based on the evaluation criteria.

Performing the Visual Inspection. Solvents stored in glass bottles can be visually inspected for peroxides. Bottles containing organic solvents are typically made of amber/brown glass, so a flashlight can be used to light the interior of the bottle. During the inspection, you should look for signs that the material is contaminated:

1. Hard crystal formations in the form of ice like structures, crystals, solid masses or an obscure cloudy medium signify gross contamination.

2. Wisp like structures floating in a clear liquid suspension signify contamination. Use caution when performing the inspection as peroxide formation may be present anywhere in the container such as the bottom, sides, threaded cap, or anywhere else on the outside of the container.

3. If any of the above indicators are noted contact EHLS immediately. Do not move the container and refrain from working with containers/materials near the suspect container.

Containers passing the initial screening may be tested for peroxide content. Four peroxide detection methods are commonly used. They include two qualitative variations on the iodine detection method, the qualitative ferrous thiocyanate method, and the use of semi-quantitative redox dip strips. While any of these methods may be used, dip strips provide the highest sensitivity and the most accurate quantification of peroxide concentration for routine testing. They are easier, faster, and safer to use than other methods and detect a wider range of peroxides. However, dip strips are inconvenient to use for testing nonvolatile solvents and have a limited shelf life. A common dip strip test used is the MQuant Peroxide Test Strip (0-100 ppm range).

Assessing Peroxide Levels:

- Note date last tested.
- Confirm identity and age of chemical and that it's within safe storage period.
- CAUTION: Never try to force open a rusted or stuck cap on a container of a peroxide forming material.
- < 25 ppm – Considered safe for general use.
- 25 – 99 ppm – Not recommended for distilling or otherwise concentrating.
- > 100 ppm – Avoid handling and contact EHLS for disposal.

Peroxide Forming Materials Storage

Peroxide-forming chemicals shall be should be stored in sealed, air-impermeable, light-resistant containers and should be kept away from light (light can initiate peroxide formation). Peroxide-forming chemicals should be stored in their original manufacturer's container whenever possible. This is very important in the case of diethyl ether because the iron in the steel containers that

the material is shipped in acts as a peroxide inhibitor. Keep away from sources of ignition. Containers should be dated when opened and tested periodically for the presence of peroxides. Do not exceed storage time limits. Peroxides are sensitive to heat, friction, and shock. Some peroxides may explode without being concentrated. (e.g. Isopropyl Ether.)

Chemical Name: Peroxide Forming Chemicals

STANDARD OPERATING PROCEDURES

Type of SOP: ☒Hazardous Class ☐Hazardous Chemical ☐Process

According to the Safety Data Sheets (SDS) for Peroxide Forming Chemicals, special precautions must be taken when working with these types of materials. This Standard Operating Procedure (SOP) briefly describes the use of equipment and supplies maintained in the lab/facility, procedures that must be followed, and the responsibilities of personnel when working in these labs/facilities. The PI or the designee should **amend this SOP by modifying the text highlighted in yellow to include specifics for your lab(s). Users shall** not conduct experiments, even pilot studies, which are not described in this approved SOP. It is essential that all personnel follow the appropriate procedures outlined in this SOP. **Please provide the SDS associated with this chemical.**

PI Information

Name:	
Dept.:	
PS ID:	
Date:	

1. PI Responsibilities (Please click the Check Box on every shaded section header.)	
☐	The PI is responsible for training students/employees using the chemical. The training should include a discussion of the known and potential hazards and an explanation of the relevant policies, techniques and procedures including the proper use of personal protective equipment and containment equipment.
☐	Students/employees should be trained initially and then annually thereafter. Their knowledge, competence and practices should be evaluated and documented.
☐	Implement a safety program and include this information in the chemical hygiene plan.
☐	Limit access to authorized users.
☐	Minimize the possibility of direct skin or eye contact with the drug or inadvertent ingestion/inhalation.
☐	Transportation of the chemical within the facility should be performed using a sealed non-breakable secondary container.
☐	Develop Standard Operating Procedures (SOP) for delivery and storage of the chemical. The SOP should have a contingency plan for broken or leaking bottles.
☐	Properly label containers and any secondary containers of the chemical.
☐	Provide SDS via email to ehs@uh.edu upon request.

2. Chemicals/Hazards

- Chemical Name(s) and CAS Number(s): Various. See table 1 below.
- **NOTE**: **This is not an exhaustive list**. Users **must** consult the manufacturer's SDS and/or other sources of information for the chemicals used (and stored) to determine their peroxide-forming potential.
- Peroxide formation in common laboratory chemicals is caused by an autoxidation reaction. The reaction can be initiated by light, heat, introduction of a contaminant, oxygen or the loss of an inhibitor. Some chemicals have inhibitors such as BHT (butylated hydroxytoluene), hydroquinone, and diphenylamine to slow peroxide formation.
- Most organic peroxide crystals are sensitive to heat, shock, or friction, and their accumulation in laboratory reagents has resulted in numerous explosions. For this reason, it is important to identify and control chemicals which form potentially explosive peroxides
- In general, the more volatile the compound, the greater its hazard, since the evaporation of the compound allows the peroxide to concentrate. Peroxide accumulation is a balance between peroxide formation and degradation. Refer to the tables below for some common peroxide forming chemicals and testing procedures. Organic peroxide forming materials can form shock-sensitive organic peroxide crystals over time or upon exposure to air.
- **Check each material's SDS to determine if a chemical can form peroxides, and to check for other hazards.**
- Special Circumstances of Use in your lab: XXX

List A: Chemicals that form explosive levels of peroxides without concentration (3 months)[1, 2]		
Butadiene[2] (106-99-0) • *Pyrrolene* • *Vinylethylene*	Isopropyl Ether (108-20-3) • *Diisopropyl ether* • *Diisopropyl oxide*	• Sodium Amide (7782-92-5)
Chloroprene[2] (126-99-8) • *Chlorobutadiene*	Potassium Amide (17242-52-3)	Tetrafluoroethylene[2] (116-14-3) • *Perfluoroethylene*
Divinyl Acetylene (821-08-9)	Potassium Metal (7440-09-7)	Vinylidene Chloride (75-35-4)

		• *1,1-dichloroethylene* *1,1-dichloroethene*
List B: Chemicals that form explosive levels of peroxides on concentration (12 months)[1]		
1,1-Dimethoxymethane (109-87-5) • *Methylal* • *Methylene dimethyl ether*	Benzyl n-butyl Ether (588-67-0)	Dioxane (123-91-1) • *Diethylene ether*
1,2-Epoxy-3-isopropoxy propane (4016-14-2) • *Isopropyl glycidyl ether*	Benzyl Ether (103-50-4) • *Dibenzyl ether*	Diethyl Ether (60-29-7) • *Ethyl ether*
1-pentene (109-67-1) • *Propyl ethylene*	Benzyl Ethyl Ether (539-30-0)	Ethylene Glycol Dimethyl Ether (110-71-4) • *1,2-dimethoxyethane* • *EGDME* • *Glyme*
1-Phenylethanol (98-85-1) • *sec-phenethyl alcohol*	Benzyl 1-naphthyl Ether (607-58-9)	Furan (110-47-4)
2-Butanol (78-92-2) • *Sec-butyl alcohol*	Cumene (98-82-8) • *Isopropyl benzene*	Isoamyl Ether (544-01-4) • *Isopentyl ether*
2-Hexanol (626-93-7) • *n-hexanol* • *Amylcarbinol* • *Caproyl alcohol*	Cyclohexene (110-83-8) • *Tetrahydrobenzene*	Isophorone (78-59-1)
2-Methyl-1-butanol (137-32-6) • *secondary isoamyl alcohol* • *sec-butylcarbinol* • *active amyl alcohol*	Cyclooctene (931-88-4)	Methyl Isobutyl Ketone (108-10-1)
4-Penten-1-ol (821-09-0)	Cyclopentene (142-29-0)	Methyl Acetylene (74-99-7) • *Propyne*
2-Phenylethanol (60-12-8) • *Benzyl carbinol* • *Benzylmethanol*	Decahydronapthalene (91-17-8) • *Decalin* • *DeKalin*	Methylcyclopentane (96-37-7)
2-Propanol (67-63-0) • *Isopropanol*	Diacetylene (460-12-8)	Other secondary alcohols
4-Heptanol (589-55-9)	Diallyl Ether (557-40-4) • *Propenyl ether*	p-Dibenzyloxybenzene (621-91-0)
4-Methyl-2-pentanol (108-11-2) • *Methyl isobutyl carbinol*	Dicyclopentadiene (77-73-6)	p-Isopropoxypropionitrile (110-47-4)
4-Penten-1-ol (821-09-0)	Diethoxymethane (462-95-3)	Tetrahydrofuran (109-99-9)
Acetal (105-57-7)	Isoamyl benzyl ether (122-73-6)	Tetrahydronaphthalene (119-64-2)

• *Diethylacetyl* • *ethylidene diethyl ether*		• *Tetralin* • *Tetranap*
Acetaldehyde (75-07-0)	Diethylene Glycoldimethyl Ether (111-96-6) • *Diglyme*	Diethyl acetal (105-57-7)
Allyl Ether (557-40-4)	Dimethoxymethane (109-87-5) • *Methylene dimethyl ether* • *Methylal*	Vinyl Ethers
Benzyl alcohol (100-51-6) • *Hydroxytoluene* • *Phenyl carbinol*	Di-n-propoxymethane (505-84-0)	
List C: Chemicals that may autopolymerize as a result of peroxide accumulation (12 months)[1,3,4]		
Acrylic Acid (79-10-7) • *2-propenoic acid* • *Vinylformic acid* • *Acroleic acid*	Methyl Methacrylate (80-62-6) • *2-propenoic acid*	Vinylidene chloride (75-35-4) • *1,1-dichloroethylene* • *1,1-dichloroethene*
Acrylonitrile (107-13-1) • *Vinyl cyanide* • *Carbacryl*	Styrene (100-42-5)	• 2-Vinyl Pyridine (100-69-6)
Butadiene[2] (106-99-0) • *Pyrrolene* • *Vinylethylene*	Tetrafluoroethylene[2] (116-14-3) • *Perfluoroethylene*	4-Vinyl Pyridine (100-43-6)
Chloroprene[2] (126-99-8)	Vinyl Acetate (108-05-4)	
Chlorotrifluoroethylene (79-38-9)	Vinyl Acetylene (689-97-4)	
Ethyl Acrylate (140-88-5) • *Ethyl 2 propenoate* • *Acrylic acid ethyl ester*	Vinyl Chloride (75-01-4) • *Chloroethylene*	

3. Engineering Controls

- Use fume hood or other appropriate exhaust ventilation if inhalation hazard is anticipated. Utilize shields, barricades, and additional PPE (such as face shields with throat protectors and heavy gloves). Work with Peroxide Forming chemicals should be done in a properly functioning chemical fume hood.
- Any eyewash station is strongly recommended in immediate work area.

Please list the locations of the eye wash, safety shower and fume hood below.

Type	Location (Building and Room Numbers)
Fume Hood(s) **Safety Shower (s)** **Eyewash Station(s)**	

4. Personal Protective Equipment (PPE)

- Lab coat, safety glasses and nitrile gloves are required. Leave lab coats in the lab when your work is complete to prevent the spread of this or other chemicals outside of the lab.
- Respiratory protection may be needed if aerosol hazard is present and work is conducted outside of a fume hood. If any procedure may pose an external hazard it should be eliminated or strictly isolated. If a potential exposure hazard cannot be eliminated, please contact the EHLS Respiratory Protection Program administrator to discuss respiratory protection or to enroll in the program. Program enrollment includes medical evaluation, training and fit testing for an appropriate respirator. For information see EHLS Respiratory Protection Program or email ehs@uh.edu.

5. Work Practice Controls (Preparation and Handling)

Preparation

- Consider alternate methods and use a safer alternative if possible.
- Purchase peroxide formers with inhibitors added by the manufacturer when possible.
- Do not allow materials to evaporate to near dryness unless absence of peroxides has been shown.
- This SOP must be approved in advance by the Principal Investigator.
- Provide lab-specific training by the PI or designee to personnel working with Peroxide Forming Chemicals and any other personnel authorized are required to be in the laboratory or shared work space.
- Confirm fume hood, emergency eyewash and/or shower are located within working area and that all have a current certification date.
- Review Standard for Storing & Utilizing Peroxidizable Organic Chemicals (Lawrence Livermore National Laboratory – 1999) at the following link. https://e-reports-ext.llnl.gov/pdf/235232.pdf

Handling

- **Mark the container with the *date it was received* and *the date it was opened*. If tested for peroxides, note the date it was tested.**
- Time Limited Material Labels can be found at the link below. https://www.uh.edu/ehls/labs/labels/Time-limited-primary-container.pdf
- Periodically test containers with peroxide test strips. Any container found to have a peroxide concentration greater than or equal to 100 ppm should be disposed of.

- Note: some peroxide formers (including alkali metals and their amides) should not be tested with standard peroxide tests because they are both water and oxygen-reactive.
- Materials which are older than the suggested shelf life but have been tested and have no detectable peroxides or peroxide concentrations less than 100 ppm may be retained but should be re-tested. Table 1 List A chemicals should be retested monthly while List B chemicals should be retested every three months (see Table 2). *All chemicals which are to be distilled must be tested prior to distillation regardless of age.*
- **Important note: Researchers should never test containers of unknown age or origin. Older containers are far more likely to have concentrated peroxides or peroxide crystallization in the cap threads and therefore can present a serious hazard when opened for testing. Please read section below on managing older containers.**

6. Work Practice Controls (Storage and Transport)

STORAGE

- Store in airtight containers in a dark, cool but not freezing, and dry area.
- Do not permit sources of heat, friction, grinding, or impact near storage areas.
- Some peroxide-formers should be stored under nitrogen (or other inert gas) – consult the manufacturer's SDS for more information.
- Peroxide forming chemicals should be stored and used under an inert atmosphere, when practical.
- Only essentially anhydrous alcohols are subject to peroxidation. Solutions of alcohols with water (e.g., rubbing alcohol, which is 70% 2-propanol and 30% water) are not subject to peroxidation and do not need to be labeled, tracked, or tested. This exemption does not apply if these materials are used for chemical operations such as distillations and synthetic reactions.

7. Spill and Accident Procedures
[Specific cleaning and waste disposal procedures must be determined.]

Chemical spills must be cleaned up as soon as possible by properly protected and trained personnel. All other persons should leave the area. Spill response procedures must be developed based on the chemical and potential spill or release conditions. Clean up spills using contents of the laboratory spill kit. Do not attempt to clean up any spill if not trained or comfortable. If the spill is large or more concentrated or people have been exposed, evacuate the area and call 911 on campus phone or 713-743-3333 for help. If a person is exposed follow EXPOSURE PROCEDURES in section 8 below.

SPILL CLEANUP PROCEDURES

1. Close hood sash, cordon off area.

2. If you need help, call EHLS (during business hours (M-F/8-5) 713-743-5858, outside business hours call 911 on campus phone or 713-743-3333). Tell them that a chemical spill has occurred and you need advice or assistance. Notify supervisor.
3. Personnel must wear a fully buttoned lab coat with sleeves extended to wrists, face shield and safety goggles, nitrile gloves, long pants (or other clothing covering the entire leg), closed toed shoes.
4. All spill cleanup materials and absorbents should be bagged or placed in a sealed container with a hazardous waste label.
5. Contact EHLS for Waste Disposal.

8. Exposure Procedures In Case of Emergency

1. **Provide First Aid Immediately**
   - For **inhalation** exposure, move out of contaminated area. Call 911 on campus phone or 713-743-3333.
   - For **eye or skin** exposure, call 911 on campus phone or 713-743-3333. Use the safety eyewash for at least 15 minutes or until medical treatment is given.
2. **Get Help**
   - Call 911 on campus phone or 713-743-3333 or go to nearest Emergency Department to seek medical attention. Give details of exposure:
     - Chemical name and concentration
     - Amount of exposure
     - Route of exposure (skin, eyes, respiratory)
     - Time since exposure
   - Bring the SDS and SOP for the specific Peroxide Forming chemical to the Emergency Department.
   - Notify your supervisor as soon as possible for assistance.
   - Secure area before leaving. Lock doors and indicate spill if needed.
3. **Report Incident to Environmental Health and Life Safety**
   - Notify EHLS immediately after providing first aid and/or getting help.
     - During business hours (M-F/8-5) call 713-743-5858.
     - After hours call 911 on campus phone or 713-743-3333 to be routed to EHLS staff on call.
   - For all incidents and near misses, the involved person or supervisor should report to EHLS at 713-743-5858.

9. Waste Disposal

WASTE COLLECTION AND DISPOSAL

1. Most spent, unused, or expired materials are considered Unwanted Material and must be disposed of as Regulated Waste within 90 days and must be collected by EHLS.

- Label waste with EHLS Unwanted Material Waste label stating the primary hazards (peroxide former, toxic, etc.), PI name, & concentration. Waste labels are available on EHLS's website.

2. Other peroxide forming chemical waste

Grossly contaminated gloves, absorbent pads, and all spill cleanup materials are hazardous waste.

- Accumulate waste in a plastic bag.
- Label with EHLS Unwanted Material Hazardous Waste label as above.

3. Disposal

For chemical waste pickup: Complete Online waste pickup request form.

4. Contacts

For questions regarding chemical and hazardous chemical collection

- visit the EHLS Chemical Waste website or,
- email ehs@uh.edu or,
- call 713-743-5858

5. **Contacts** Contact EHLS i***mmediately*** to arrange for pick-up and disposal if:

- Crystals are found around the lid of the container
- The container tests positive for peroxides
- **Do NOT attempt to open the container**!

10. Lab-specific Protocol/Procedure

This SOP must be customized for each lab using Peroxide Forming Chemicals. Use this section to describe or attach what is being done with Peroxide Forming Materials, including specific laboratory procedures and quantities used.

Particularly Hazardous Substance involved?	__ YES:	Blocks #11 to #13 are Mandatory
	__ NO:	Blocks #11 to #13 are Optional.

11. Approval Required

All staff working with Peroxide Forming chemicals must be trained on this SOP prior to starting work. They must also be trained on the individual peroxide formers SDS, and it must be readily available in the laboratory. All training must be documented and maintained by the PI or their designee.

12. Decontamination

All surfaces and non-disposable equipment will be decontaminated by the methods described in the manufacturer's SDS.

13. Designated Area

- All work with peroxide forming materials must be done in a designated laboratory, work space and fume hood. This work will be conducted in *[room #]*.

PI's Name:	PISD:
Department:	Date:
Signature:	

[Laboratory Name]
Documentation of Training*
Standard Operating Procedure for Peroxide Forming Materials

"I have read and understand this SOP. By signing below, I agree to fully adhere to its requirements."

Last	First	PSID	Email	Signature	Date

* This document, including the signature page with signatures by all involved personnel shall be maintained by the Principal Investigator or Designee, and be submitted to EHLS either electronically via the ehs@uh.edu or hard copy upon request.